BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

ANNUAL MEETING, 1934

(104TH YEAR)

ABERDEEN

SEPTEMBER 5-12

LONDON

OFFICE OF THE BRITISH ASSOCIATION

BURLINGTON HOUSE, LONDON, W. 1

1934

CONTENTS.

* See note on following page.

APPENDIX.

* SECTIONAL PRESIDENTS' ADDRESSES: CORRIGENDA.

SECTION C: PRESIDENT'S ADDRESS.

Page 51, footnote. *Read* Cochran Patrick, R. W., *Early Records relating to Mining in Scotland*, 1878. An undated lease of rather earlier date, probably before the end of the twelfth century, is recorded in Chalmers' *Caledonia*, n.e., 1889, vol. iv, p. 866. See also Cadell, H. M., *The Rocks of West Lothian*, 1925, p. 313.

Page 57, line 13. *For* " elephant " *read* " elephants' bones."
Page 63, line 7 from foot. *After* " not " *read* " to."
Page 65, line 12 from foot. *For* " re-Palæozoic " *read* " pre-Palæozoic."
Page 70, line 4. *For* " Wegner " *read* " Wegener."
Page 71, line 14. *Read* " precursors." Line 18, *read* " Alpine."
Page 75, line 7. *For* " mistaken " *read* " misunderstood."
Page 79, line 2 from foot. *For* " little " *read* " practically no."

SECTION I: PRESIDENT'S ADDRESS.

Page 178, Note 18. *For* lines 7 to 11, commencing " This matter " and ending " sensation of blue," *read* " The matter must be left in abeyance, but the use of the term ' violet receptor ' is to be understood to mean either the receptor for violet or blue. Owing to the fact that fatigue to ' red ' causes violet to appear more blue, Wright believes that the single receptor gives rise to a sensation of blue."

SECTION J: PRESIDENT'S ADDRESS.

Page 190, line 19. *For* 99 *read* 109.

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TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27......	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S. ...	—	—
1835, Aug. 10......	Dublin..................	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22......	Bristol..................	The Marquis of Lansdowne, F.R.S. ...	—	—
1837, Sept. 11......	Liverpool	The Earl of Burlington, F.R.S..........	—	—
1838, Aug. 10......	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26......	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester............	The Lord Francis Egerton, F.G.S.......	303	169
1843, Aug. 17	Cork......................	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26......	York	The Rev. G. Peacock, D.D., F.R.S....	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10......	Southampton	Sir Roderick I. Murchison, Bart.,F.R.S.	241	10
1847, June 23 ...	Oxford..................	Sir Robert H. Inglis, Bart., F.R.S. ...	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres.R.S.	149	3
1849, Sept. 12......	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.......	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast..................	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull......................	William Hopkins, F.R.S..................	141	13
1854, Sept. 20......	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12......	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeney, M.D., F.R.S. .	182	14
1857, Aug. 26......	Dublin..................	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22......	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14......	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A., F.R.S. ...	286	21
1861, Sept. 4	Manchester............	William Fairbairn, LL.D., F.R.S........	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26......	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13......	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22......	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19......	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18......	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S. ...	204	21
1870, Sept. 14......	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S. ...	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S. .	246	28
1872, Aug. 14......	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17......	Bradford	Prof. A. W. Williamson, F.R.S..........	212	27
1874, Aug. 19......	Belfast	Prof. J. Tyndall, LL.D., F.R.S..........	162	13
1875, Aug. 25......	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S..........	221	35
1877, Aug. 15......	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14......	Dublin..................	W. Spottiswoode, M.A., F.R.S..........	201	18
1879, Aug. 20......	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25......	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31......	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23......	Southampton	Dr. C. W. Siemens, F.R.S...............	178	17
1883, Sept. 19......	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27......	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S. ...	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S. ...	314	25
1887, Aug. 31......	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11......	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.......	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19......	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13 ...	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11......	Ipswich	Sir Douglas Galton, K.C.B., F.R.S. ...	214	13
1896, Sept. 16......	Liverpool	Sir Joseph Lister, Bart., Pres. R.S. ...	330	31
1897, Aug. 18......	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13......	Dover	Sir Michael Foster, K.C.B., Sec. R.S. ...	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xiv.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1832
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1110*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

[*Continued on p.* xv.

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11......	Glasgow	Prof. A. W. Rücker, D.Sc., Sec. R.S.	310	37
1902, Sept. 10......	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S....	419	32
1905, Aug. 15	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin..................	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31......	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30......	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10......	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July–Sept.	Australia...............	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S....................	242	19
1916 Sept. 5	Newcastle-on-Tyne	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9......	Bournemouth.........	Hon. Sir C. Parsons, K.C.B., F.R.S....	235	47
1920, Aug. 24	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12......	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.	119	7
1925, Aug. 26......	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9
1927, Aug. 31	Leeds	Sir Arthur Keith, F.R.S.	249	9
1928, Sept. 5	Glasgow	Sir William Bragg, K.B.E., F.R.S.......	260	10
1929, July 22	South Africa	Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S.	81	1
1930, Sept. 3	Bristol	Prof. F. O. Bower, F.R.S.	221	5
1931, Sept. 23......	London	Gen. the Rt. Hon. J. C. Smuts, P.C., C.H., F.R.S.	487	14
1932, Aug. 31......	York	Sir Alfred Ewing, K.C.B., F.R.S.	206	1
1933, Sept. 6	Leicester	Sir F. Gowland Hopkins, Pres. R.S. ...	185	37
1934, Sept. 5	Aberdeen	Sir James H. Jeans, F.R.S.[14]	199	21

[1] Including 848 Members of the South African Association.
[2] Including 137 Members of the American Association.
[3] Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.
[4] Including Students' Tickets, 10s.
[5] Including Exhibitioners granted tickets without charge.
[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0 0	410 0 0	1919
Old Annual Regular Members	Annual Members: Meeting and Report	Annual Members: Meeting only	Transferable Tickets	Students' Tickets				
136	192	571	42	120	20	1380	1272 10 0	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15 0	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5 0	722 0 7	1922
					Complimentary[7]				
123	380	1434	163	550	308	3296	2735 15 0	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19 0[10]	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5 0	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0 0	917 1 6	1926
84	334	1487	82	264	161	2670	2414 5 0	761 10 0	1927
76	554	1835	64	201	74	3074	3072 10 0	1259 10 0	1928
24	177	1227[11]	—	161	83	1754	1477 15 0	1838 2 1	1929
68	310	1617	97	267	54	2639	2481 15 0	683 5 7	1930
78	656	2994	157	454	449	5702[12]	4792 10 0	1146 7 6	1931
44	226	1163	45	214	125	2024	1724 5 0	1183 13 11	1932
39	236	1468	82	147	74	2268	2428 2 0	412 19 11[13]	1933
30	273	1884	181	280	70	2938	2900 13 6	739 4 0	1934

[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.

[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.

[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.

[11] Including 450 Members of the South African Association.

[12] Including 413 tickets for certain meetings, issued at 5*s*. to London County Council school-teachers.

[13] For nine months ending March 31, 1933.

[14] Sir William B. Hardy, F.R.S., who became President on January 1, 1934, died on January 23.

NARRATIVE OF THE ABERDEEN MEETING.

On Wednesday, September 5, at 8.30 p.m., the Inaugural General Meeting was held in the Capitol Cinema (generously placed by the management at the disposal of the Association), when the Hon. the Lord Provost of Aberdeen (Mr. Henry Alexander, J.P.) and the Principal and Vice-Chancellor of the University (the Very Rev. Sir George Adam Smith, D.D.) welcomed the Association to Aberdeen. The President of the Association, Sir James H. Jeans, F.R.S., delivered an Address (for which see p. 1) entitled *The New World Picture of Modern Physics*.

Before delivering his Address, the President read the following message which had been forwarded to The King at Balmoral, and His Majesty's gracious reply:—

Your Majesty,—We, the Members of the British Association for the Advancement of Science assembled in the City of Aberdeen in annual session, desire humbly to recall to Your Majesty that it was in this City that His Royal Highness The Prince Consort assumed the Presidency of the Association in the year 1859. From the Presidential Chair, he conveyed to the assembled members of the Association a gracious message from Her Majesty Queen Victoria, and delivered an Address which disclosed his own profound interest in the advancement of Science. The many marks of Royal favour which have been extended to our Association on subsequent occasions have provided further signal encouragement to us in our pursuit of the aims defined by His Royal Highness, and on all these counts we now desire to express to Your Majesty our humble gratitude.

(*Signed*) J. H. Jeans,
President.

To The President,
The British Association, Aberdeen.

I am commanded by the King to thank the members of the British Association for the Advancement of Science for the loyal message which they have addressed to His Majesty, their Patron, from the Inaugural General Meeting in the Ancient City of Aberdeen.

His Majesty appreciates their kind remembrance of the occasion when the Prince Consort, as President of the Association, delivered a message from Queen Victoria to the members assembled in this City three-quarters of a century ago.

The King desires me to assure the members of his unabated interest in their Meetings and his confidence that their investigations into the manifold problems confronting present day Scientists will continue to be productive of results which will benefit mankind.

(*Signed*) Clive Wigram.

5th September, 1934.

On Friday, September 7, in the MacRobert Hall, Gordon's College, at 8.30 p.m., Sir Frank Smith, K.C.B., Sec. R.S., delivered an Evening Discourse entitled *The Storage and Transport of Food* (see p. 419), being

a Memorial Lecture for the late President of the Association, Sir William Hardy, F.R.S.

On Monday, September 10, in the same hall, at 8.30 P.M., Prof. W. L. Bragg, F.R.S., delivered an Evening Discourse entitled *The Exploration of the Mineral World by X-rays* (p. 437).

* * * * * *

The Lord Provost, Magistrates, and Town Council of Aberdeen entertained members of the Association at a Reception in the Art Gallery and adjacent buildings on Thursday evening, September 6.

The University of Aberdeen entertained members of the Association at a Garden Party in King's College on Monday afternoon, September 10.

A dance was held in the Beach Ball Room on Tuesday evening, September 11.

The students of Aberdeen University produced a play, *Town & Gown*, during the week beginning on September 10, and the productions on this and the following nights were regarded as 'British Association performances.'

By the courtesy of the owners, the exhibits shown at the Telford Centenary Exhibition in the Institution of Civil Engineers, London, in June, 1934, were displayed in the Engineering Department of Gordon's College during the week of the meeting. The exhibition was opened by Sir Alexander Gibb, G.B.E., on Friday, September 7.

Visits were arranged to the Rowatt Research Institute, the Macaulay Research Institute, the Torry Research Station of the Department of Scientific and Industrial Research, and the research vessel (the *Explorer*) of the Fishery Board for Scotland; and numerous other institutions and works in the city and neighbourhood afforded facilities and entertainment to members during the meeting.

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A special service was held in the West Church of St. Nicholas, when officers and other members of the Association accompanied the Lord Provost in state. The service was conducted by the Rev. P. C. Millar, O.B.E., Minister of the Church, and the preacher was the Very Rev. Principal Sir George Adam Smith, D.D. The service was broadcast, and the sermon was published in *The Listener*, September 26. Other special services were held in St. Andrew's Cathedral, St. Mary's Roman Catholic Cathedral, and Belmont Congregational Church.

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On Saturday, September 8, general excursions were arranged to Royal Deeside, the Highlands (Spey Valley, Aviemore, Culloden Moor, Inverness), Moray (Elgin, Pluscarden Abbey, etc.), Mearns (Glen of Dye, Cairn o' Mount road, Fettercairn, Edzell, Brechin, Stonehaven). Among other excursions and visits, those devoted to the interests of special Sections during the Meeting are mentioned among the Sectional Transactions in later pages.

* * * * * *

At the final meeting of the General Committee, on Tuesday, September 11, it was resolved:

(1) That the British Association places on record its warm thanks for the hospitable reception afforded to it by the City of Aberdeen. The

generous co-operation of the Lord Provost, Magistrates, and Town Council, and the thorough preparations made by the local officers and committees, have been deeply appreciated, while the large local membership has been highly gratifying to the Association.

(2) That the British Association most cordially thanks the University Court of the University of Aberdeen for their hospitality to the Association, for the use of their buildings, and for the valuable assistance given by the University authorities and staff.

(3) That the British Association most cordially thanks the scientific educational, commercial, and industrial institutions in Aberdeen and the neighbourhood, for the accommodation and facilities so generously provided for meetings and visits.

* * * * * *

On Wednesday, September 12, the President and General Officers, Members of the Council and Presidents of Sections, entertained the principal local officers at luncheon.

REPORT OF THE COUNCIL, 1933–34.

PRESIDENCY, 1934.

I.—The Association suffered a grievous loss in the death of its President, Sir William Hardy, F.R.S., on January 23.

The Council adopted the following resolution :—

That the Council deeply deplore the death of the President of the Association, Sir William Hardy, remember with gratitude his eminent services in the advancement of science, and record their sincere condolence with the members of his family in their bereavement.

A letter was received from the Lord Provost of Aberdeen (Mr. Henry Alexander) expressing the regret of the Local General Committee for the Aberdeen Meeting.

The Association was represented at the funeral of the late President by Prof. Lord Rutherford, F.R.S., ex-President, by Prof. F. J. M. Stratton, General Secretary, and by Mr. D. B. Gunn, Town Clerk Depute of Aberdeen, on behalf of the Local General Committee.

Sir William Bragg, O.M., K.B.E., F.R.S., occupied the Chair of the Council at the meetings in February and March.

The Council resolved that one of the Evening Discourses at the Aberdeen Meeting should be announced as a Sir William Hardy Memorial Lecture.

II.—On the nomination of the Council, Sir James Jeans, F.R.S., was appointed to succeed Sir William Hardy as President of the Association for the current year, at a meeting of the General Committee convened on March 2 by the Council under Statute II, 3.

OBITUARY.

III.—The Council have had to deplore the loss by death of the following office-bearers and supporters :—

Most Hon. the Marquis of Aberdeen
Dr. F. A. Bather, F.R.S., a member of the present Council
Sir John H. Biles, F.R.S.
Dr. Lilian Clarke
Prof. Sir Edgworth David, F.R.S.
Prof. J. Cossar Ewart, F.R.S.
Prof. W. M. Hicks, F.R.S.
Prof. J. Joly, F.R.S.
Sir Donald Macalister, K.C.B.
Prof. A. B. Macallum, F.R.S.
Prof. J. E. Marr, F.R.S.
Sir Ernest Moir, Bt.
Dr. Marion Newbigin
The Hon. Lady Parsons
Dr. W. Rosenhain, F.R.S.
Dr. D. H. Scott, F.R.S., General Secretary, 1900–03
Prof. J. Y. Simpson
Prof. S. H. Vines, F.R.S.
Prof. R. Ramsay Wright

The Association was represented at the funeral of Dr. Bather by Prof. P. G. H. Boswell, F.R.S., General Secretary, and at that of Dr. D. H. Scott by Prof. F. E. Weiss, F.R.S.

Representation.

IV.—Representatives of the Association have been appointed as follows :—

Central Conference for Health Education, London	Dr. C. W. Kimmins
National Committee for Geodesy and Geophysics	Prof. A. O. Rankine, F.R.S.
American Association for the Advancement of Science, Boston Meeting .	Prof. F. E. Lloyd and Prof. A. E. Kennelly
British Film Institute, Advisory Committee	Prof. J. L. Myres
International Congress of Anthropology and Ethnology, London . . .	Capt. T. A. Joyce
Edinburgh Geological Society, Centenary .	Prof. P. G. H. Boswell, F.R.S.

The Council have given general approval to a suggestion that, except on occasions of special formality or otherwise in the discretion of the General Secretaries, it should be competent for the Secretary to send a letter to inviting bodies indicating that representatives are not nominated unless special circumstances make such action desirable, but that among such circumstances would be included any specific proposal or suggestion for collaboration between the inviting society and the Association or any of its sectional or research committees, with the object of the advancement of science in any department within the scope of the Association.

Resolutions.

V.—Resolutions referred by the General Committee to the Council for consideration, and, if desirable, for action, were dealt with as follows. The resolutions will be found in the Report for 1933, p. xliv.

(*a*) The recommendation received from the General Officers was in the following terms :—

> That it be a recommendation to the General Committee to request the Council to consider by what means the Association, within the framework of its constitution, may assist towards a better adjustment between the advance of science and social progress, with a view to further discussion at the Aberdeen Meeting.

A committee of the Council considered this recommendation, and drew up a Memorandum which, after amendment and adoption by the Council, was circulated to all Organising Sectional Committees. As a result, numerous subjects appropriate to the terms of the recommendation have been included for discussion in sectional programmes for the Aberdeen Meeting, and the Council themselves have had the recommendation in mind when arranging the evening meetings.

(*b*) A letter was addressed to the Ministry of Agriculture and Fisheries expressing the hope that no effort would be spared to exterminate the musk-rat completely in this country. A reply was received to the effect that the danger was fully appreciated, and that suitable measures were being taken. (Resolution of Section D, Zoology.)

(*c*) After inquiry, no action was taken upon a recommendation that the inclusion of population maps in the Census returns should be urged upon the proper authorities. (Resolution of Section E, Geography.)

(*d*) The attention of the Colonial Office was drawn to the backward state of geodetic surveys in the British colonies and dependencies, and a reply was received to the effect that the question was continually engaging the attention of the Secretary of State, and that the Council's representation would not be overlooked, but that it was difficult for most of the dependencies to find funds for survey work outside ordinary revenue purposes. (Resolution of Section E, Geography.)

(*e*) A communication on the desirability of accelerating the revision of the large-scale maps of the Ordnance Survey was addressed to the Ministry of Agriculture and Fisheries. (Resolution of Section E, Geography.)

(*f*) The attention of the Ministry of Agriculture and Fisheries was drawn to the desirability of investigating diseases of the cricket-bat willow, and a reply was received to the effect that research into the diseases mentioned was already being carried on under the Forestry Commission, and that some work had also been done at Long Ashton Research Station. (Resolution of Section K, Botany.)

(*g*) The separate issue of the reports on Science in Adult Education and on General Science with special reference to Biology was authorised as requested in the resolution of Section L (Educational Science).

VI.—In the Report of the Council for last year (Report, 1933, p. xx) it was stated that the Council had forwarded a resolution to H.M. Secretary of State for the Colonies, dealing with the archæological and geological interest of the Kendu-Homa area in Kenya. A reply was received to the effect that the Acting Governor of Kenya had taken steps to exclude the site in the Kendu-Homa area, on which archæological and geological discoveries had been made, from the area in respect of which application for exclusive mineral prospecting licences had been invited. The Council ordered an expression of their satisfaction to be conveyed to the authorities concerned.

VII.—Correspondence on a proposal to establish a nature reserve in the Galapagos Islands was reported to the Council, and it was resolved that a communication be forwarded to the Carnegie Institution, expressing the hope that such proposal might be carried out, having regard especially to the fact that it was contemplated that the reserve should be established as a memorial to Charles Darwin. A reply was received from the Institution, expressing appreciation of the Council's communication, and indicating that discussion was in progress with the authorities concerned.

Down House.

VIII.—The following report for the year 1933-34 has been received from the Down House Committee :—

The number of visitors to Down House during the year ending June 6, 1934, has been 8,536, compared with 7,022 in 1932-33. The increase is believed to be due, at least in part, to the establishment of an omnibus service to the village of Downe.

Sir Buckston Browne has generously presented to the house his portrait by Mr. Robin Darwin. It is peculiarly appropriate that this work of Darwin's great-grandson should find its place here.

Several gifts of letters and other Darwiniana have been received during the past year and duly acknowledged, and have also been recorded in an addendum to the catalogue recently compiled.

Under a scheme in which Mr. G. C. Robson, Prof. J. W. Munro, Miss Saunders of Goldsmiths' College, and others are interested, opportunity has been given teachers in training and other students to do work on plant ecology in the neighbourhood of Downe, and they have made some use of accommodation at Down House in this connection. The Committee feel that it is most appropriate that the Association should be able to grant such facilities.

The Secretary and Mrs. Howarth have written, and published at their own charges, a *History of Darwin's Parish : Downe, Kent*, to which Sir Arthur Keith has contributed a foreword. The Committee have consented to the announcement of this work along with other announcements relating to Down House in Association programmes, and have allowed it to be on sale at the house, as well as through ordinary channels.

The following financial statement shows income and expenditure on account of Down House for the financial years ending March 31, 1933 and 1934. For the latter year, a balance of income over expenditure amounting to £45 9*s*. 8½*d*. is shown. The gift from the Pilgrim Trust, acknowledged in the last report of the Committee, has thus relieved the general funds of the Association. As the Council were advised last June, the present and any subsequent balance on the side of receipts will not be payable automatically to general funds, but will be placed in a suspense or maintenance fund for the house. If any payment to general funds should ultimately be considered possible, it will be by way of interest upon the so-called capital expenditure incurred on the property from general funds.

It was explained in last year's report that the figure for income from the endowment fund for 1932-33 was deceptive, as certain dividends included both a gross payment for the year and a refund of income tax on the preceding year. This accounts for the apparent, but not actual, decrease in the returns on the invested fund.

Income

	1932-33 £ s. d.	1933-34 £ s. d.
By Dividends on endowment fund and income tax recovered . . .	1,030 1 10	978 17 6
,, Grant from Pilgrim Trust . .	—	150 0 0
,, Rents	138 0 0	140 15 0
,, Donations	7 4 4	6 0 11½
,, Sale of Postcards and Catalogues .	24 17 0	34 14 2½
,, Balance, being excess of expenditure, as below, over income . . .	40 7 11½	—
	£1,240 11 1½	1,310 7 8

Expenditure (running costs)

	1932-33 £	s.	d.	1933-34 £	s.	d.
To Wages and National Insurance	807	2	10	831	18	8
,, Rates, Land Tax, Insurances	64	10	11	57	4	10½
,, Coal, Coke, etc.	104	9	9	103	12	5
,, Water	15	6	8	15	4	1
,, Lighting and Drainage Plants (including petrol and oil)	69	17	6	62	18	3½
,, Repairs and Renewals	39	8	7	35	9	0
,, Garden Materials	58	10	9	56	14	8
,, Household Requisites, etc.	16	19	3½	17	6	10½
,, Transport and Carriage	5	5	2	2	1	1
,, Auditors	22	10	10	19	1	2
,, Printing, Postages, Telephone, Stationery, etc.	36	8	10	41	6	4
,, Donations to Village Institutions	—			5	5	0
,, Legal Charges (lease of 'Homefield')	—			7	5	6
,, Purchase of Darwin's dining table (net)	—			9	10	0
,, Balance, being excess of income over expenditure	—			45	9	8½
	£1,240	11	1½	1,310	7	8

Finance.

IX.—The Council have received reports from the General Treasurer throughout the year. His account has been audited and is presented to the General Committee.

X. *Bernard Hobson Trust.*—As stated in last year's Report of the Council, the Association was a beneficiary in the sum of £1,000 under the will of Mr. Bernard Hobson, the income from which is to be devoted to the promotion of definite geological research. The Council have confirmed the proposals indicated in the last report, in the following terms :—

(i) The fund is administered by the Council.

(ii) It shall be competent for the Committee of Section C (Geology) at the Annual Meeting to recommend to the Council that one or more of the applications for grants to research committees shall be earmarked as a charge on the Bernard Hobson Fund.

(iii) Council reserves the right to make a grant, or grants, from the fund in response to special applications arising in the course of the year.

The Council undertook to consider the payment of travelling expenses (fares) in connection with grants made from the fund.

XI. *Sir Charles Parsons' Legacy.*—The legacy of £2,000 left to the Association by the Hon. Sir Charles Parsons, K.C.B., F.R.S., has been received.

XII. *Leicester and Leicestershire Fund* (1933).—On behalf of the Local Committee for the Leicester Meeting, 1933, Dr. C. J. Bond and Mr. Colin

Ellis presented a cheque for £1,000 as a gift to the Association, being unexpended balance of the fund raised locally for the purposes of the meeting. The following conditions were proposed :—

(1) That the sum of £1,000 be given to the British Association for the Advancement of Science to be invested by them, the interest to be used to assist by scholarship or otherwise a student or students working for the advancement of science.

(2) That the fund be administered solely by the Council of the British Association.

(3) That when possible assistance be given preferably to a Leicester or Leicestershire student or worker.

(4) That the fund be called the 'Leicester and Leicestershire Fund,' or in some other way be identified with Leicester and Leicestershire, and that it be referred to in each year in the annual statement of the British Association.

It was resolved that the Council accept with gratitude from the Committee for the Leicester Meeting (1933) their gift of the sum of £1,000 to the Association, to form the Leicester and Leicestershire Fund for the prosecution of scientific work ; that the terms of trust accompanying the gift be accepted, and that the Council record their appreciation of the action of the committee in thus confirming, in a manner without precedent in the history of the Association, their interest in the advancement of science.

XIII. *Grants.*—The Council made the following grants from funds under their control :—

From the Caird Fund.

	£
Committee on Seismology	100
,, ,, Critical Sections in Palæozoic Rocks	20 (contingent)
,, ,, Plymouth Table	50
,, ,, Zoological Record	50
,, ,, Naples Table	50
,, ,, Fresh Water Biological Station, Windermere (out of total grant of £75)	40
,, ,, Derbyshire Caves	25
,, ,, Prehistoric Site in Rio Tinto	15 (contingent)
,, ,, Routine Manual Factor in Mechanical Ability	20 ,,

(The above gave effect to recommendations made at the Leicester Meeting.)

Committee on Mathematical Tables, toward the publication of Bessel Function Tables	£100
Contribution toward expenses of Sixth International Congress for Scientific Management	£5 5*s*.
Committee on Human Geography of Tropical Africa, not exceeding	£5

From the Bernard Hobson Fund.

Committee on Character of the Palæozoic Rocks underlying the Carboniferous of the Craven area	£30

(Giving effect to a recommendation made at the Leicester Meeting.)

From the Cunningham Bequest.

Prof. W. E. H. Berwick in connection with Table of Reduced Ideals . . . . £10 10*s.*

XIV.—The Council propose the following additional Statute, to form paragraph (v) of section 2 in Chapter X, on the *Admission and Privileges of Members* :—

Corporation membership may be acquired by any British corporate body approved by the Council on payment of the sum of thirty guineas which shall entitle the corporation to appoint one representative to attend each annual meeting in perpetuity, or on payment of the sum of fifty guineas, two representatives, and on payment of each further sum of fifteen guineas, an additional representative. Such subscription shall entitle the corporation or each of its representatives to receive the annual report on demand.

President (1935), General Officers, Council and Committees.

XV.—The Council's nomination to the Presidency of the Association for the year 1935 (Norwich Meeting) is Prof. W. W. Watts, F.R.S.

XVI.—*The General Officers* have been nominated by the Council as follows :—

General Treasurer, Sir Josiah Stamp, G.B.E.

General Secretaries, Prof. F. J. M. Stratton, D.S.O., O.B.E., Prof. P. G. H. Boswell, O.B.E., F.R.S.

XVII. *Council.*—The retiring Ordinary Members of the Council are : Sir Henry Fowler, K.B.E., Dr. Tate Regan, F.R.S., Prof. J. F. Thorpe, F.R.S., and Sir John Russell, F.R.S. A further vacancy was created by the death of Dr. F. A. Bather, F.R.S., to which previous reference has been made.

The Council have nominated as new members Sir T. Hudson Beare, Prof. A. V. Hill, F.R.S., and Dr. W. W. Vaughan, leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows :—

Prof. F. Aveling
Sir T. Hudson Beare
Prof. R. N. Rudmose Brown
Prof. F. Balfour Browne
Sir Henry Dale, C.B.E., Sec. R.S.
Prof. J. Drever
Prof. A. Ferguson
Prof. R. B. Forrester
Prof. W. T. Gordon
Prof. Dame Helen Gwynne-Vaughan, G.B.E.
Dr. H. S. Harrison
Sir James Henderson
Prof. A. V. Hill, F.R.S.
Prof. G. W. O. Howe
Dr. C. W. Kimmins
Sir P. Chalmers Mitchell, C.B.E.
Dr. N. V. Sidgwick, F.R.S.
Dr. G. C. Simpson, C.B., F.R.S.
H. T. Tizard, C.B., F.R.S.
Prof. A. M. Tyndall, F.R.S.
Dr. W. W. Vaughan
Dr. J. A. Venn
Prof. F. E. Weiss, F.R.S.

XVIII. *Secretary.*—At their meeting in February the Council congratulated Dr. O. J. R. Howarth, Secretary, on completing twenty-five years in office.

XIX. *General Committee.*—The following have been admitted as members of the General Committee, mostly on the nomination of the Organising Sectional Committees under Regulation 1 :—

Dr. S. Bryan Adams
Mrs. Robert Aitken
Prof. G. C. Allen
Dr. C. B. Allsopp
Prof. E. V. Appleton, F.R.S.
Mr. W. T. Astbury
Dr. W. A. Bain
Dr. Helen Bancroft
Dr. H. Banister
Dr. B. Barnes
Mr. B. Hilton Barrett
Mr. R. J. Bartlett
Mr. M. G. Bennett
Dr. J. D. Bernal
Miss D. Bexon
Mr. E. G. Bowen
Dr. J. A. Bowie
Mr. M. C. Burkitt
Dr. J. A. V. Butler
Mr. L. H. Dudley Buxton
Prof. H. Graham Cannon
Miss G. Caton-Thompson
Dr. A. W. Chapman
Prof. V. Gordon Childe
Prof. J. E. Coates
Dr. J. D. Cockcroft
Miss E. R. Conway, C.B.E.
Dr. R. S. Creed
Mr. E. H. Davison
Prof. J. Doyle
Prof. J. C. Drummond
Miss M. Drummond
Mr. T. S. Dymond
Prof. L. E. S. Eastham
Mr. W. N. Edwards
Mr. A. C. G. Egerton, F.R.S.
Capt. F. Entwistle
Mr. E. Farmer
Mrs. Allan Ferguson
Prof. R. A. Fisher, F.R.S.
Prof. P. Sargant Florence
Prof. C. Daryll Forde
Mr. C. H. H. Franklin
Mr. J. A. Fraser
Dr. R. G. Gordon
Dr. Ezer Griffiths, F.R.S.
Dr. J. M. Gulland
Dr. R. T. Gunther
Dr. T. M. Harris
Mr. R. F. Harrod
Prof. H. R. Hassé
Prof. H. L. Hawkins
Prof. W. N. Haworth, F.R.S.
Prof. I. M. Heilbron, F.R.S.
Dr. E. L. Hirst
Mr. S. R. Humby
Dr. J. O. Irwin
Dr. J. Wilfred Jackson
Mr. H. E. O. James
Dr. S. W. Kemp, F.R.S.
Prof. L. A. L. King
Mr. J. F. Kirkaldy
Mr. A. R. Knight
Dr. Margery Knight
Dr. S. K. Kon
Dr. E. V. Laing
Prof. J. E. Lennard-Jones, F.R.S.
Mr. A. G. Lowndes
Dr. W. H. McCrea
Prof. B. A. McSwiney
Dr. T. G. Maitland
Capt. L. W. G. Malcolm
Dr. F. G. Mann
Dr. S. M. Manton
Miss H. Masters
Prof. J. R. Matthews
Prof. E. Mellanby, F.R.S.
Dr. G. H. Miles
Mr. A. A. Miller
Prof. E. A. Milne, M.B.E., F.R.S.
Dr. E. M. Musgrave
Mr. V. E. Nash-Williams
Mr. R. M. Neill
Prof. J. J. Nolan
Mr. J. R. Norman
Dr. W. G. Ogg
Prof. L. S. Palmer
Mr. C. F. A. Pantin
Dr. S. J. F. Philpott
Prof. W. J. Pugh
Dr. A. Raistrick
Dr. F. Raw

Prof. H. H. Read
Prof. E. K. Rideal, M.B.E., F.R.S.
Mr. N. D. Riley
Prof. G. W. Robinson
Mr. G. C. Robson
Dr. F. J. W. Roughton
Rev. J. P. Rowland, S.J.
Mr. R. U. Sayce
Miss L. I. Scott
Mr. D. J. Scourfield
Dr. L. Simons
Prof. J. L. Simonsen, F.R.S.
Dr. Bernard Smith, F.R.S.
Prof. J. G. Smith
Mr. T. Smith, F.R.S.
Mr. W. Campbell Smith
Dr. F. G. Soper
Mr. A. Stevens
Dr. James Stewart
Dr. R. Stoneley
Dr. J. D. Sutherland
Prof. E. G. R. Taylor
Mr. T. W. J. Taylor
Mr. E. R. Thomas
Dr. R. H. Thouless
Mr. E. Tillotson
Dr. J. F. Tocher
Dr. W. S. Tucker, O.B.E.
Dr. G. W. Tyrrell
Miss M. D. Vernon
Dr. H. C. Versey
Prof. J. Walton
Dr. R. E. Mortimer Wheeler
Mr. W. Hamilton Whyte
Prof. F. J. Wilson
Dr. J. Wishart
Dr. A. Wohlgemuth
Dr. S. W. Wooldridge
Dr. Dorothy M. Wrinch

XX. *Corresponding Societies Committee.*—The Corresponding Societies Committee has been nominated as follows :—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Treasurer, the General Secretaries, Mr. C. O. Bartrum, Sir Richard Gregory, F.R.S., Sir David Prain, F.R.S., Dr. A. B. Rendle, F.R.S., Prof. W. M. Tattersall, Prof. W. W. Watts, F.R.S., Dr. R. E. Mortimer Wheeler.

Future Annual Meetings.

XXI.—It has been reported to the Council that invitations have been received for the Association to meet in Cambridge in 1938 and in Dundee in 1940 ; and these will be laid before the General Committee.

Miscellanea.

XXII. *Commemorative Rolls and Panels.*—The Council have considered schemes alternative to the presidential banners formerly exhibited in the Reception Rooms at Annual Meetings, and have adopted a scheme which they hope will commend itself to members of the Association generally.

XXIII. *The Catalogue of Bronze Age Implements*, compiled by a committee of the Association, has been taken over by the British Museum.

XXIV. *Mathematical Tables.*—The Council desire to call the attention of the General Committee to the following appreciation of the work of the Mathematical Tables Committee. It appears in the preface to *Funktionentafeln* by Jahnke and Emde (Teubner, 1933), and runs (in translation) as follows :—

> As in the first edition, great use has been made of the work of the British Association Mathematical Tables Committee. Fortunately this committee has decided to publish collections of the very accurate tables which they have calculated in past years. Two volumes have already

been published. The mathematicians, physicists, and engineers of the whole world regard with the greatest wonder and gratitude this colossal undertaking of their English colleagues, who have taken upon themselves almost entirely the load of new computation. It is hardly to be conceived that other countries will continue much longer to look idly on without helping in this work.

XXV. *Town and Country Planning.*—The Council approved a proposal to receive information from the Ministry of Health relating to town and country planning, with a view to reporting upon areas which appear to require protection for scientific reasons. Such information is now being received, and communication is proceeding between the Association and those of its own Corresponding Societies which may be concerned in this important matter, while other interested bodies are also being consulted.

XXVI. *Inland Water Survey.*—Following upon the issue last year of a report by the Committee on an Inland Water Survey, the co-operation of the Institution of Civil Engineers in the further consideration of this question was invited and generously afforded. A letter and memorandum on the desirability of a complete and systematic survey of the water resources of the country were addressed, by the Presidents of both bodies, to the Prime Minister, and a representative deputation subsequently waited upon the Minister of Health to discuss the matter. The Minister promised careful consideration of the suggestions made.

GENERAL TREASURER'S ACCOUNT 1933-34

The outstanding incident during the financial year ending March 31, 1934, was the presentation to the Association of the sum of £1,000 on behalf of the Leicester Committee, being the balance in excess of expenditure on the fund raised (as usual) locally in connection with the Leicester Meeting. This gift, which is more fully referred to in the Report of the Council, is to be regarded as an unprecedented compliment to the Association, for hitherto balances (if any) on local funds have been disposed of by local committees themselves, although in two instances (Liverpool and Oxford) they have been devoted to the assistance of students attending Association meetings.

The payment of the legacy from Sir Charles Parsons reminds us of all that the Association previously owed to this splendid benefactor.

Apart from this and other matters mentioned in the Report of the Council there is little to report in matters of detail. In my report last year I expressed the hope that the excess of expenditure over income on account of Down House would not recur, thanks to the generous gift of the Pilgrim Trustees ; and this hope has been fulfilled. I also stated that the growth of advertisement revenue, under the then existing conditions of depression, could not be expected to continue ; and the revenue from this source is in fact seriously diminished.

The usual practice of furnishing in the year's accounts comparative figures for the preceding year is intermitted in the present instance because the accounts presented last year, owing to the change of dates for the financial year, covered a period of nine months only, and comparisons would therefore be of no value. The practice will be resumed next year.

The form in which the accounts are presented has been altered so as to bring more readily to the eye the position of the various funds administered by the Association. In working out this new scheme, occasion was taken to note certain legacies and other gifts which, not being given for special purposes, have not appeared individually in the accounts since the years in which they were received. In this year of meeting at Aberdeen, where the Prince Consort presided at the first meeting, in 1859, it is appropriate to recall that in 1846–7 he made a donation of £100 to the Association. The list of legacies, apart

from those recently received from the estates of Sir Charles Parsons, Mr. Bernard Hobson, and Lt.-Col. Alan Cunningham, is as follows :

Year		£	s.	d.
1863–4	Beriah Botfield, of Ludlow . .	10	10	0
1870–1	Alexander Robb . . .	100	0	0
1920–1	William Palmer	104	4	0
1921–2	T. W. Backhouse . . .	500	0	0
1927–8	Professor A. W. Scott . .	250	0	0

JOSIAH C. STAMP,
General Treasurer.

Balance Sheet as

LIABILITIES

		£ s. d.	£ s. d.
General Purposes :—			
Sundry Creditors		68 13 9	
Hon. Sir Charles Parsons' gift (£10,000) and legacy (£2,000)		12,000 0 0	
Yarrow Fund			
As per last Account . .	£6,142 14 8		
Less Transferred to Income and Expenditure Account under terms of the gift .	411 0 0		
		5,731 14 8	
Life Compositions			
As per last Account . .	2,079 12 2		
Add Received during year .	462 0 0		
	2,541 12 2		
Less Transferred to Income and Expenditure Account	51 0 0		
		2,490 12 2	
Contingency Fund			
As per last Account . .	375 0 0		
**Add* Amount transferred from Income and Expenditure Account	394 17 11		
		769 17 11	
Accumulated Fund			
As at 1st April, 1933 .	17,701 16 0		
Less Down House Suspense Account written off as *per contra*	1,213 7 0		
		16,488 9 0	
			37,549 7 6
Carried forward . .			37,549 7 6

* The amount which should, in accordance with Council's resolution, have been in the Contingency Fund at 31st March, 1934, was £875, but the surplus income available for this purpose has been insufficient by £105 2*s*. 1*d*. to meet the full annual amount transferable.

at 31st March, 1934

ASSETS

	£ s. d.	£ s. d.
General Purposes :—		
Investments, as scheduled with Income and Expenditure Account, No. 1	36,770 1 11	
Catalogues in Stock, at cost (Down House)	83 17 0	
Sundry debtors and payments in advance	73 16 9	
Cash at bank	601 16 7	
Cash in hand (as per contra)	19 15 3	
		37,549 7 6
Carried forward		37,549 7 6

Continued on pages xxxiv *and* xxxv

Balance Sheet as

LIABILITIES (*continued*)

	£ s. d.	£ s. d.	£ s. d.
Brought forward . .			37,549 7 6
Special Purposes :—			
Caird Fund			
Balance at 1st April, 1933 .	9,741 14 11		
Add Excess of Income over Expenditure for year . .	25 16 1		
		9,767 11 0	
Cunningham Bequest			
Balance at 1st April, 1933 .	2,968 10 3		
Less Transferred to Income and Expenditure Account .	551 12 0		
	2,416 18 3		
Less Excess of Expenditure over Income for the year .	131 19 2		
		2,284 19 1	
Toronto University Presentation Fund			
Capital	178 11 4		
Revenue	4 7 6		
		182 18 10	
Bernard Hobson Fund			
Capital	1,000 0 0		
Revenue—Excess of Income over Expenditure for year	22 10 6		
		1,022 10 6	
Leicester and Leicestershire Fund, 1933			
Capital		1,000 0 0	
Down House			
Endowment Fund . .	20,000 0 0		
Sundry Creditors . .	28 4 2		
Suspense Account . .	45 9 8½		
		20,073 13 10½	
			34,331 13 3½
			£71,881 0 9½

NOTE.—There are contingent Liabilities in respect of grants voted to Research Committees at Leicester in 1933, but not claimed at 31st March, 1934, amounting to £478 18*s*. 3*d*. and £130 in respect of Grants voted by Council to other objects.

I have examined the foregoing Account with the Books and Vouchers and certify Investments, and the Bank have certified to me that they hold the Deeds of Down year and I have verified the receipt of the proceeds.

Approved.
ARTHUR L. BOWLEY
W. W. WATTS } *Auditors.*
21st June, 1934.

at 31st March, 1934 (*continued*)

ASSETS (*continued*)

	£ s. d.	£ s. d.	£ s. d.
Brought forward . . .			37,549 7 6
Special Purposes :—			
Caird Fund			
Investments (see Income and Expenditure Account, No. 2) .	9,582 16 3		
Cash at bank	184 14 9		
		9,767 11 0	
Cunningham Bequest			
Investments (see Income and Expenditure Account, No. 3) .	2,151 7 2		
Cash at bank	133 11 11		
		2,284 19 1	
Toronto University Presentation Fund			
Investments (see Income and Expenditure Account, No. 4) .	178 11 4		
Cash at bank	4 7 6		
		182 18 10	
Bernard Hobson Fund			
Investments (see Income and Expenditure Account, No. 5) .	1,000 0 0		
Cash at bank	22 10 6		
		1,022 10 6	
Leicester and Leicestershire Fund, 1933			
Investments (see Income and Expenditure Account, No. 6) .		1,000 0 0	
Down House			
Endowment Investments (see Income and Expenditure Account, No 7)	20,000 0 0		
Cash at bank	37 0 3		
Cash in hand . . .	14 11 10½		
Sundry debtors and payments in advance . . .	22 1 9		
		20,073 13 10½	
			34,331 13 3½
			£71,881 0 9½

the same to be correct. I have also verified the Balances at the Bankers and the House. The Mortgage on Isleworth House has been paid off since the close of the

W. B. Keen,
Chartered Accountant.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 1934.

No. 1. General Income and Expenditure

Investments :

Nominal	Investment	£	s.	d.	
£6,749 12s. 2d.	Consolidated 2½ per cent. Stock, at cost	5,142	3	3	
£3,600 0s. 0d.	India 3 per cent. Stock, at cost	3,522	2	6	
£879 14s. 9d.	Great Indian Peninsula Railway 'B' Annuity £43, at cost	827	15	0	
£52 12s. 7d.	War Stock (Post Office Issue), at cost	54	5	2	
£834 16s. 6d.	4½ per cent. Conversion Stock, at cost	835	12	4	
£1,400 0s. 0d.	3½ per cent. War Loan Bonds, at cost	1,393	16	11	
£7,679 6s. 6d.	3½ per cent. War Loan Inscribed Stock, at cost	7,703	10	8	
£10,394 7s. 0d.	4½ per cent. Conversion Stock, at cost	10,062	15	0	
£5,692 2s. 10d.	3½ per cent. Conversion Stock, at cost	4,604	8	11	
£2,949 12s. 4d.	3 per cent. Local Loans, at cost	1,923	12	2	
	Second Mortgage on Isleworth House, Orpington, Kent	700	0	0	(Value of Stocks at 29/3/34,
		£36,770	1	11	£40,170 3s. 11d.)

EXPENDITURE

	£	s.	d.	£	s.	d.
To Heat, Lighting and Power	35	1	7			
,, Stationery	83	19	2			
,, Rent	1	0	0			
,, Postages	229	1	0			
,, Travelling expenses	180	13	9			
,, Exhibitioners	37	8	8			
,, Badges	127	6	7			
,, Audit and Accountancy	40	16	10			
,, Sundries	205	0	6½			
	940	8	1½			
,, Salaries and wages	1,964	11	0			
,, Pension contribution	75	0	0			
,, Printing, binding, etc..	1,395	10	8			
				4,375	9	9½

INCOME

	£	s.	d.	£	s.	d.
By Old Annual Regular Members	110	7	0			
,, Annual members for Meeting only	1,513	11	0			
,, Annual members, with Report	367	0	0			
,, Transferable Tickets	102	10	0			
,, Student members	73	10	0			
				2,166	18	0
,, Life compositions : amount transferred on expiry of membership				51	0	0
,, Sale of Publications				474	16	2½
,, Advertisements in B.A. publications				285	3	1
,, Unexpended balances of grants, returned				65	9	6
,, Liverpool Exhibitioners				22	10	0
,, Income Tax recovered				105	0	5

	£	s.	d.	£	s.	d.
To Grants made to Research Committees by General Committee 1932, 1933:						
General Science in Schools	19	0	1			
Cretaceous and Tertiary London Rocks	15	0	0			
Sumerian Copper	25	0	0			
Kent's Cavern	5	0	0			
Sex Ratio in Guinea Pigs	5	0	0			
Freshwater Biological Station	60	0	0			
Science Teaching in Adult Education Classes	10	0	0			
Behaviour of Plankton Population	6	9	5			
Anatomy of Timber-producing trees	10	0	0			
Ainu Studies	50	0	0			
Woodland Maps	25	0	0			
Mathematical Tables	33	17	6			
Mount Carmel excavations	30	0	0			
				294	7	0
,, Balance being excess of income over expenditure for the year carried down				394	17	11
				£5,064	14	8½
To transfer to Contingency Fund				394	17	11
				£394	17	11
Grants voted at 1933 Meeting, but not claimed to date				293	18	3
Amount voted to Parsons Memorial Fund not yet paid				100	0	0
				£393	18	3

	£	s.	d.
By Interest on investments	1,477	0	8
,, Donations	5	16	10
,, Sir Alfred Yarrow's Gift: amount transferred	411	0	0
	£5,064	14	8½
By balance brought down	394	17	11
	£394	17	11

No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

Investments:

		£	s.	d.
£2,627 0s. 10d.	India 3½ per cent. Stock, at cost	2,400	13	3
£2,100 0s. 0d.	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock, at cost	2,190	4	3
£2,500 0s. 0d.	Canada 3½ per cent. Registered Stock, 1930/50, at cost	2,397	1	6
£2,000 0s. 0d.	Southern Railway Consolidated 5 per cent. Preference Stock, at cost	2,594	17	3
		£9,582	16	3

(Value at 29/3/34, £8,876 0s. 3d.)

EXPENDITURE

	£	s.	d.	£	s.	d.
To Grants paid—						
Naples Table Committee	50	0	0			
Mathematical Tables Committee	50	0	0			
Derbyshire Caves Committee	25	0	0			
Seismology Committee	100	0	0			
Plymouth Table Committee	50	0	0			
Freshwater Biological Station Committee	40	0	0			
Congrès International des Sciences Anthropologiques et Ethnologiques	10	0	0			
Sixth International Congress for Scientific Management	5	5	0			
				330	5	0
,, Balance, being excess of income over expenditure for the year				25	16	1
				£356	1	1
Grants to research authorised, but not yet claimed				155	0	0
Grant towards Sir J. B. Harrison's monograph, 'The Katamorphism of Igneous Rocks under Tropical and Temperate Conditions,' not yet paid				30	0	0
				£185	0	0

INCOME

	£	s.	d.
By Dividends and Interest	287	13	8
,, Income Tax recovered	68	7	5
	£356	1	1

(Cash at bank, £184 14s. 9d.)

No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers; administered by the Council.

Investments :

Nominal	Stock	£	s.	d.
£1,187 6*s*. 10*d*.	Consolidated $2\frac{1}{2}$ per cent. Stock	653	0	9
£300 0*s*. 0*d*.	Port of London $3\frac{1}{2}$ per cent. Stock, 1949/99	216	0	0
£100 0*s*. 0*d*.	Commonwealth of Australia $4\frac{3}{4}$ per cent. Stock	93	0	0
£100 0*s*. 0*d*.	New Zealand 5 per cent. Stock, 1946	103	0	0
£1,554 3*s*. 1*d*.	Local Loans 3 per cent. Stock, at cost	1,086	6	5
		£2,151	7	2

(Value at 29/3/34, £2,906 12*s*. 9*d*.)

EXPENDITURE

	£	s.	d.	£	s.	d.
To Purchase of Calculating Machine (capital charge)	550	0	0			
,, Loss on redemption of India 6 per cent. Stock (capital charge)	1	12	0			
				551	12	0
,, Grants for preparation of tables				114	12	0
,, Printing				132	8	9
				£798	12	9

INCOME

	£	s.	d.
By Transfer from capital	551	12	0
,, Interest	103	10	6
,, Income Tax recovered	11	11	1
,, Excess of Expenditure over Income for the year	131	19	2
	£798	12	9

(Cash at bank, £133 11*s*. 11*d*.)

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

Investment :

£175 $3\frac{1}{2}$ per cent. War Stock at cost . . . . . £178 11 4 (Value at 29/3/34, £182)

EXPENDITURE

	£	s.	d.
To awards	£6	2	6

INCOME

	£	s.	d.
By Interest	£6	2	6

(Cash at bank, £4 7*s*. 6*d*.)

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson; the income to be applied to the promotion of geological research; administered by the Council.

Investments:

		£	s.	d.	
£450 0*s.* 0*d.*	4 per cent. Victory (Bearer) Bonds, at cost	491	13	6	
£601 9*s.* 0*d.*	3 per cent. Local Loans, at cost	508	6	6	
		£1,000	0	0	(Value at 29/3/34, £1,051 14*s.* 2*d.*)

EXPENDITURE		INCOME	
To Excess of income over expenditure for the year	£22 10 6	By Interest	£22 10 6
(Grant authorised, not yet claimed, £30)		(Cash at bank, £22 10*s.* 6*d.*)	

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

Investments:

		£	
£487 2*s.* 11*d.*	$3\frac{1}{2}$ per cent. Conversion Stock at cost	500	
£490 5*s.* 11*d.*	$3\frac{1}{2}$ per cent. War Stock at cost	500	
		£1,000	(Value at 29/3/34, £1,011 8*s.* 4*d.*)

There is no income or expenditure within the period of these accounts.

No. 7. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (now Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment to the Association as a gift to be held as a memorial to Darwin in trust for the nation.

Investments :

	Down House Endowment Fund	£	s.	d.
£5,500	India 4½ per cent. Stock 1958/68, at cost	5,001	17	4
£2,500	Commonwealth of Australia 5 per cent. Stock 1945/75, at cost	2,468	19	0
£3,000	Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock, at cost	2,139	17	3
£2,500	New South Wales 5 per cent. Stock, 1945/65, at cost	2,467	7	9
£2,500	Western Australia 5 per cent. Stock, 1945/75, at cost	2,472	1	6
£3,340	Great Western Railway 5 per cent. Guaranteed Stock, at cost	3,436	7	5
£2,500	Birkenhead Railway 4 per cent Consolidated Stock, at cost	2,013	9	9
		£20,000	0	0

(Value at 29/3/34, £23,882 8*s.* 0*d.*)

EXPENDITURE

	£ s. d.	£	s.	d.
To Wages of Staff		831	18	8
,, Rates, insurance, etc.		57	4	10½
,, Coal, Coke, etc.		103	12	5
,, Lighting and Drainage (including oil and petrol)		62	18	3½
,, Legal charges on lease of 'Homefield'		7	5	6
,, Water		15	4	1
,, Repairs and Renewals		35	9	0
,, Garden Materials, etc.		56	14	8
,, Donations		5	5	0
,, Household Requisites, etc.		17	6	10½
,, Transport and carriage		2	1	1
,, Accountants' Fees		19	1	2
,, Printing, Postages, Telephone, Stationery		41	6	4
,, Purchase of Darwin's dining table	12 10 0			
Less sale of old table	3 0 0			
		9	10	0
,, Balance, being excess of income over expenditure for the year, transferred to Suspense Account		45	9	8½
		£1,310	7	8

INCOME

	£	s.	d.
By Rents Receivable	140	15	0
,, Income Tax recovered	171	2	6
,, Interest and Dividends	807	15	0
,, Donations	6	0	11½
,, Sale of Postcards and Catalogues	34	14	2½
,, Pilgrim Trust grant	150	0	0
	£1,310	7	8

(Cash at bank, £37 0 3
,, in hand 14 11 10½
£51 12 1½)

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN ABERDEEN, 1934.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological Investigations.—Dr. F. J. W. Whipple (*Chairman*), Mr. J. J. Shaw, C.B.E. (*Secretary*), Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. C. Vernon Boys, F.R.S., Sir F. W. Dyson, K.B.E., F.R.S., Dr. Wilfred Hall, Dr. H. Jeffreys, F.R.S., Prof. Sir Horace Lamb, F.R.S., Mr. A. W. Lee, Prof. H. M. Macdonald, O.B.E., F.R.S., Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., Rev. J. P. Rowland, S.J., Mr. D. H. Sadler, Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Capt. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Dr. R. Stoneley, Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S. **£150** (£100 Caird Fund grant).

Calculation of Mathematical Tables.—Prof. E. H. Neville (*Chairman*), Dr. L. J. Comrie (*Secretary*), Prof. A. Lodge (*Vice-Chairman*), Dr. J. R. Airey, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. F. Robbins, Mr. D. H. Sadler, Dr. A. J. Thompson, Dr. J. F. Tocher, Dr. J. Wishart. **£100** (Council to consider additional grant not exceeding £200 to expedite printing).

SECTIONS A, C.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOLOGY.

The direct determination of the Thermal Conductivities of Rocks in mines or borings where the temperature gradient has been, or is likely to be, measured.—Dr. Ezer Griffiths, F.R.S. (*Convener*), Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S. (*from Section A*); Mr. E. M. Anderson, Prof. W. G. Fearnsides, F.R.S., Prof. A. Holmes, Dr. D. W. Phillips, Dr. J. H. J. Poole, Mr. W. Campbell Smith (*from Section C*). **£30** (part on Bernard Hobson Fund).

SECTIONS A, C, E, G.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOLOGY, GEOGRAPHY, ENGINEERING.

To inquire into the position of Inland Water Survey in the British Isles and the possible organisation and control of such a survey by central authority.—Vice-Adml. Sir H. P. Douglas, K.C.B., C.M.G. (*Chairman*), Lt.-Col. E. Gold, D.S.O., F.R.S. (*Vice-Chairman*), Capt. W. N. McClean (*Secretary*), Mr. E. G. Bilham, Prof. W. S. Boulton, Dr. Brysson Cunningham, Prof. C. B. Fawcett, Prof. W. G. Fearnsides, F.R.S., Prof. A. Ferguson, Mr. H. J. F. Gourley, Dr. Ezer Griffiths, F.R.S., Mr. W. T. Halcrow, Mr. T. Shirley Hawkins, O.B.E., Prof. G. Hickling, Dr. Murray Macgregor, Mr. W. J. M. Menzies, Mr. H. Nimmo, Dr. A. Parker, Mr. D. Ronald, Capt. J. C. A. Roseveare, Dr. Bernard Smith, F.R.S., Mr. C. Clemesha Smith, Dr. L. Dudley Stamp, Mr. F. O. Stanford, O.B.E., Mr. A. Stevens, Mr. R. C. S. Walters, Brig. H. S. L. Winterbotham, C.M.G., D.S.O., Dr. S. W. Wooldridge. **£10.**

SECTIONS A, J.—MATHEMATICAL AND PHYSICAL SCIENCES, PSYCHOLOGY.

The possibility of quantitative estimates of Sensory Events.—Prof. A. Ferguson (*Chairman*), Dr. C. S. Myers, C.B.E., F.R.S. (*Vice-Chairman*), Mr. R. J. Bartlett (*Secretary*), Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Dr. S. Dawson, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houstoun, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, F.R.S., Dr. R. H. Thouless, Dr. W. S. Tucker, O.B.E.

SECTION B.—CHEMISTRY.

To advise the Sectional Committee as to the best method of meeting the wishes of Council as expressed in the memorandum on the Relation between the Advance of Science and the Life of the Community.— (*Chairman*), (*Secretary*), Dr. N. V. Sidgwick, F.R.S., Prof. J. F. Thorpe, C.B.E., F.R.S., Mr. H. T. Tizard, C.B., F.R.S.

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (*Chairman*), Prof. W. G. Fearnsides, F.R.S. (*Secretary*), Prof. E. B. Bailey, F.R.S., Mr. H. C. Berdinner, Mr. W. S. Bisat, Dr. H. Bolton, Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. W. S. Boulton, Dr. E. S. Cobbold, Prof. A. H. Cox, Miss M. C. Crosfield, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Prof. E. J. Garwood, F.R.S., Mr. F. Gossling, Prof. H. L. Hawkins, Prof. G. Hickling, Prof. V. C. Illing, Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Dr. F. J. North, Dr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, F.R.S., Prof. A. E. Trueman, Dr. F. S. Wallis, Prof. W. W. Watts, F.R.S., Dr. Whittard, Dr. S. W. Wooldridge. **£40** (Bernard Hobson Fund, contingent grant).

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood, F.R.S. (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. C. V. Crook, Mr. J. F. Jackson, Mr. J. Ranson, Prof. W. W. Watts, F.R.S., Mr. R. J. Welch.

The Stratigraphy and Structure of the Palæozoic Sedimentary Rocks of West Cornwall.—Mr. H. Dewey (*Chairman*), Mr. E. H. Davison (*Secretary*), Mr. H. G. Dines, Miss E. M. Lind Hendriks, Mr. S. Hall, Dr. S. W. Wooldridge.

To consider and report upon Petrographic Classification and Nomenclature.—Dr. H. H. Thomas, F.R.S. (*Chairman*), Dr. A. K. Wells (*Secretary*), Prof. E. B. Bailey, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. Brammall, Dr. R. Campbell, Prof. A. Holmes, Prof. A. Johannsen, Dr. W. Q. Kennedy, Dr. A. G. MacGregor, Prof. P. Niggli, Prof. H. H. Read, Prof. S. J. Shand, Mr. W. Campbell Smith, Prof. C. E. Tilley, Dr. G. W. Tyrrell, Dr. F. Walker. **£5.**

To prove the character of the Palæozoic Rocks underlying the Carboniferous of the Craven area.—Prof. W. G. Fearnsides, F.R.S. (*Chairman*), Dr. R. G. S. Hudson (*Secretary*), Prof. O. T. Jones, F.R.S., Prof. W. B. R. King, O.B.E., Mr. W. H. Wilcockson.

To make recommendations to the International Geological Congress for the formation of a committee to consider geological evidence of climatic change.—Dr. W. B. Wright (*Chairman*), Mr. M. B. Cotsworth (*Secretary*), Prof. E. B. Bailey, F.R.S., Prof. W. N. Benson, Dr. G. W. Grabham, Dr. E. M. Kindle, Dr. A. Raistrick, Dr. S. W. Wooldridge.

SECTIONS C, E.—GEOLOGY, GEOGRAPHY.

To administer a grant in support of a topographical and geological survey of the Lake Rudolph area in E. Africa.—Sir Albert E. Kitson, C.M.G., C.B.E.

(*Chairman*), Dr. A. K. Wells (*Secretary*), Mr. S. J. K. Baker, Prof. F. Debenham, Dr. V. Fuchs, Prof. W. T. Gordon, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£35** (Unexpended balance).

SECTION D.—ZOOLOGY.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth, F.R.S. (*Chairman and Secretary*), Prof. H. Graham Cannon, Prof. H. Munro Fox, Prof. J. Stanley Gardiner, F.R.S. **£50** (Caird Fund grant).

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir Sidney Harmer, K.B.E., F.R.S. (*Chairman*), Dr. W. T. Calman, F.R.S. (*Secretary*), Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S. **£50** (Caird Fund grant).

To consider the position of Animal Biology in the School Curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. H. W. Ballance, Prof. E. W. MacBride, F.R.S., Miss M. McNicol, Miss A. J. Prothero, Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

The progressive adaptation to new conditions in *Artemia salina* (Diploid and Octoploid, Parthenogenetic *v.* Bisexual).—Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. F. Gross (*Secretary*), Dr. J. Gray, F.R.S., Dr. E. S. Russell, O.B.E., Prof. D. M. S. Watson, F.R.S.

To revise the leaflet on Biological Measurements and to consider what steps should be taken to increase the use made of the archives for the reception of such measurements now established at the British Museum (Natural History), South Kensington.—Prof. J. S. Huxley (*Chairman*), Prof. R. A. Fisher, F.R.S. (*Secretary*), Dr. W. T. Calman, F.R.S., Dr. J. Gray, F.R.S.

SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. J. H. Ashworth, F.R.S. (*Chairman and Secretary*), Prof. J. Barcroft, C.B.E., F.R.S., Prof. E. W. MacBride, F.R.S., Dr. Margery Knight. **£50** (Caird Fund grant).

SECTIONS D, K.—ZOOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Mr. J. T. Saunders (*Secretary*), Miss P. M. Jenkin, Dr. C. H. O'Donoghue (*from Section D*) ; Dr. W. H. Pearsall (*from Section K*). **£75.**

SECTION E.—GEOGRAPHY.

To co-operate with bodies concerned with the cartographic representation of population, and in particular with the Ordnance Survey, for the production of population maps.— (*Chairman*), Prof. C. B. Fawcett (*Secretary*), The Director General of the Ordnance Survey, Col. Sir Charles Close, K.B.E., C.B., C.M.G., F.R.S., Prof. H. J. Fleure. **£3.**

To inquire into the present state of Knowledge of the Human Geography of Tropical Africa, and to make recommendations for furtherance and development.—Prof. P. M. Roxby (*Chairman*), Prof. A. G. Ogilvie, O.B.E. (*Secretary*), Dr. A. Geddes (*Assistant Secretary*), Mr. S. J. K. Baker, Prof. C. B. Fawcett, Mr. W. Fitzgerald, Prof. H. J. Fleure, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Col. M. N. MacLeod, D.S.O., Prof. J. L. Myres, O.B.E., F.B.A., Mr. R. A. Pelham, Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£25.**

To investigate the mapping of historical data for medieval England and to take steps to advance such work.—Mr. J. N. L. Baker (*Chairman*), Dr. H. C. Darby, Mr. E. W. Gilbert, Mr. F. G. Morris, Dr. S. W. Wooldridge.

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To report on the present position of Geographical Teaching in Schools, and of Geography in the training of teachers, and, as occasion arises, to report to Council through the Organising Committee of Section E upon the practical working of Regulations issued by the Board of Education or the Scottish Education Department affecting the position of Geography in Schools and Training Colleges.— (*Chairman*), Mr. J. McFarlane (*Secretary*), Dr. W. Edward, Sir Richard Gregory, Bt., F.R.S., Prof. J. L. Myres, O.B.E., F.B.A., Mr. A. Stevens.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Chronology of the World Crisis from 1929 onwards.—Prof. J. H. Jones (*Chairman*), Dr. P. Ford (*Convener*), Mr. H. M. Hallsworth, C.B.E., Mr. R. F. Harrod, Mr. A. Radford, Prof. J. G. Smith. **£25.**

To consider the ways in which the relationship of Science to the Community may be most usefully investigated and to inquire in what directions, if any, Section F might assist such investigations.—Mr. H. M. Hallsworth, C.B.E. (*Chairman*), Dr. K. G. Fenelon (*Secretary*), Prof. R. B. Forrester, Prof. D. H. Macgregor, Prof. J. G. Smith.

SECTIONS F, G, J, L.—ECONOMIC SCIENCE AND STATISTICS, ENGINEERING, PSYCHOLOGY, EDUCATION.

Industrial Co-operation: to report on the provisions for co-ordinating and stimulating scientific work bearing on business practice, and to make recommendations.—Dr. J. A. Bowie (*Chairman*), Mr. R. J. Mackay (*Secretary*), Prof. J. G. Smith, Major L. Urwick (*from Section F*); Prof. W. Cramp (*from Section G*); Mr. G. P. Crowden (*from Section I*); Dr. C. S. Myers, C.B.E., F.R.S. (*from Section J*); Sir Richard Gregory, Bt., F.R.S. (*from Section L*).

SECTION G.—ENGINEERING.

Earth Pressures.—Mr. F. E. Wentworth-Sheilds, O.B.E. (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Prof. R. V. Southwell, F.R.S., Dr. R. E. Stradling, C.B., Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. **£7 4s. 1d.** (Unexpended balance).

Electrical Terms and Definitions.—Prof. Sir J. B. Henderson (*Chairman*), Prof. F. G. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. Cramp, Prof. W. H. Eccles, F.R.S., Prof. C. L. Fortescue, Sir R. T. Glazebrook, K.C.B., F.R.S., Prof. A. E. Kennelly, Prof. E. W. Marchant, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Prof. L. R. Wilberforce.

Stresses in Overstrained Materials.—Sir Henry Fowler, K.B.E. (*Chairman*), Dr. J. G. Docherty (*Secretary*), Prof. G. Cook, Prof. B. P. Haigh, Mr. J. S. Wilson. **£5** (Unexpended balance).

To review the knowledge at present available for the reduction of noise, and the nuisances to the abatement of which this knowledge could best be applied.—Sir Henry Fowler, K.B.E. (*Chairman*), Wing-Commander T. R. Cave-Browne-Cave, C.B.E. (*Secretary*), Mr. R. S. Capon, Dr. A. H. Davis, Prof. G. W. O. Howe, Mr. E. S. Shrapnell-Smith, C.B.E. **£5.**

SECTION H.—ANTHROPOLOGY.

To report on the Classification and Distribution of Rude Stone Monuments in the British Isles.—Mr. H. J. E. Peake (*Chairman*), Dr. Margaret A. Murray

(*Secretary*), Mr. A. L. Armstrong, Mr. H. Balfour, F.R.S., Prof. V. Gordon Childe, Dr. Cyril Fox, Mr. T. D. Kendrick.

To report on the probable sources of the supply of Copper used by the Sumerians. —Mr. H. J. E. Peake (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. Davies, Prof. H. J. Fleure, Sir Flinders Petrie, F.R.S., Dr. A. Raistrick, Dr. R. H. Rastall. **£15.**

To conduct Archæological and Ethnological Researches in Crete.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Dr. W. L. H. Duckworth, Dr. F. C. Shrubsall.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith, F.R.S. (*Chairman*), Prof. J. L. Myres, O.B.E., F.B.A. (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Miss D. A. E. Garrod, Mr. A. D. Lacaille. **£5.**

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Dr. R. V. Favell (*Secretary*), Mr. A. Leslie Armstrong, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake.

To co-operate with Miss Caton-Thompson in her researches in prehistoric sites in the Western Desert of Egypt.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. H. Balfour, F.R.S.

To report to the Sectional Committee on the question of re-editing 'Notes and Queries in Anthropology.'—Rev. E. W. Smith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Dr. H. S. Harrison, Prof. C. G. Seligman, F.R.S.

To carry out the excavation of Palæolith cave deposits on Mt. Carmel, Palestine. —Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. M. C. Burkitt (*Secretary*), Miss G. Caton-Thompson, Miss D. A. E. Garrod. **£20.**

To carry out research among the Ainu of Japan.—Prof. C. G. Seligman, F.R.S. (*Chairman*), Mrs. C. G. Seligman (*Secretary*), Dr. H. S. Harrison, Capt. T. A. Joyce, O.B.E., Rt. Hon. Lord Raglan. **£50.**

To co-operate with the local committee in the excavation of Pen Dinas hill fort, Cardiganshire.—Dr. Cyril Fox (*Chairman*), Mr. V. E. Nash-Williams (*Secretary*), Prof. V. Gordon Childe, Prof. C. Daryll Forde, Rt. Hon. Lord Raglan, Dr. R. E. M. Wheeler. **£20.**

SECTION I.—PHYSIOLOGY.

To deal with the use of a Stereotactic Instrument.—Prof. J. Mellanby, F.R.S. (*Chairman and Secretary*).

To investigate the alleged differences in distribution of rods and cones in the retinæ of various animals.—Prof. H. E. Roaf (*Chairman*), Dr. F. W. Edridge-Green, C.B.E. (*Secretary*), Prof. J. P. Hill, F.R.S., Dr. F. W. Law, Dr. S. Zuckerman. **£10.**

SECTIONS I, J.—PHYSIOLOGY, PSYCHOLOGY.

The conditions of vertigo and its relation to disorientation.—
(*Chairman*), Dr. T. G. Maitland (*Secretary*), Group-Capt. Clements, Squadron-Leader E. D. Dickson, Prof. J. H. Burn, Dr. R. S. Creed, Prof. J. Drever, Prof. J. T. MacCurdy. **£20** (Unexpended balance).

SECTION J.—PSYCHOLOGY.

To develop tests of the routine manual factor in mechanical ability.—Dr. C. S. Myers, C.B.E., F.R.S. (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear. **£30** (Leicester and Leicestershire Fund).

The nature of perseveration and its testing.—Prof. F. Aveling (*Chairman*), Mr. E. Farmer (*Secretary*), Prof. F. C. Bartlett, F.R.S., Dr. Mary Collins, Dr. W. Stephenson.

To consider definite lines of research in social psychology.—Dr. Shepherd Dawson (*Chairman*), Mr. Eric Farmer (*Secretary*), Prof. F. Aveling, Prof. F. C. Bartlett, F.R.S., Prof. C. Burt, Dr. Mary Collins, Dr. C. S. Myers, C.B.E., F.R.S.

SECTION K.—BOTANY.

Transplant Experiments.—Sir Arthur Hill, K.C.M.G., F.R.S. (*Chairman*), Dr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, F.R.S., Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S. **£5.**

The anatomy of timber-producing trees.—Prof. H. S. Holden (*Chairman*), Dr. Helen Bancroft (*Secretary*), Prof. J. H. Priestley, D.S.O. **£10.**

SECTION L.—EDUCATIONAL SCIENCE.

To consider and report on the possibility of the Section undertaking more definite work in promoting educational research.—Dr. W. W. Vaughan, M.V.O. (*Chairman*), Miss H. Masters (*Secretary*), Mr. E. R. B. Reynolds, Mr. N. F. Sheppard. **£5** (Unexpended balance).

SECTIONS M, E.—AGRICULTURE, GEOGRAPHY.

To co-operate with the staff of the Imperial Soil Bureau to examine the soil resources of the Empire.—Sir John Russell, O.B.E., F.R.S. (*Chairman*), Mr. G. V. Jacks (*Secretary*), Dr. E. M. Crowther, Dr. W. G. Ogg, Prof. G. W. Robinson (*from Section M*) ; Prof. C. B. Fawcett, Mr. H. King, Dr. L. D. Stamp, Mr. A. Stevens, Dr. S. W. Wooldridge (*from Section E*).

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Secretaries, the General Treasurer, Mr. C. O. Bartrum, Sir Richard Gregory, Bt., F.R.S., Sir David Prain, C.I.E., C.M.G., F.R.S., Dr. A. B. Rendle, F.R.S., Prof. W. M. Tattersall, Prof. W. W. Watts, F.R.S., Dr. R. E. Mortimer Wheeler.

RESOLUTIONS & RECOMMENDATIONS.

The following resolutions and recommendations were referred to the Council by the General Committee at the Aberdeen Meeting for consideration, and, if desirable, for action :—

From Sections A (Mathematical and Physical Sciences), C (Geology), E (Geography), and G (Engineering).

That the British Association awaits with great interest the result of the careful consideration which His Majesty's Government has promised to give to the question of an Inland Water Survey, and trusts that the Government will be favourable to the establishment of an organised survey of the water resources of the country on a scientific basis.

From Section C (Geology).

Section C recommends that the Government be urged to make compulsory the registration of wells, borings and excavations exceeding 100 feet in depth, under conditions similar to those for the notification and registration of shafts and boreholes for mineral, contained in the Mining Industry Act of 1926.

From Section D (Zoology).

The Committee of Section D draws the attention of the General Committee to the fact that, although technical cinematograph films for the advancement of scientific knowledge may be imported duty free for exhibition before scientific institutions, there is no provision for the free importation of films for the teaching of science in universities and similar institutions ; and requests them to instruct Council to take steps to secure the duty-free importation, by recognised teaching bodies, of technical films to be used solely for the teaching of science, under conditions similar to those which apply to films for scientific institutions, provided such films are unobtainable in Great Britain.

From Section E (Geography).

The Committee of Section E invites the Council of the British Association to make a vigorous appeal to the Lord President of the Council and to the Minister of Agriculture and Fisheries to take such measures as may ensure the provision of ample funds to carry out a far-sighted policy of large-scale maps revision in the general interest of the community.

(The above resolution was supported by Sections C, D, F, G, H, J, K, L and M.)

From Section E (Geography).

The Committee of Section E desires Council to bring to the notice of the Board of Education and the Scottish Education Department the Atlas of Geographical Types of the British Isles (of which one sheet has been published), and in view of the support lent by the Ordnance Survey to urge the desirability of continuing its production.

From Section K (Botany).

This Section requests the Council of the Association to urge upon the Department of Education in England and the Scottish Education Department, the need for instruction in all schools on the importance of the preservation of amenities, and in particular on the protection of trees, woodlands and all natural vegetation.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Aberdeen, 1934.

THE PRESIDENTIAL ADDRESS

THE NEW WORLD-PICTURE OF MODERN PHYSICS

BY

SIR JAMES H. JEANS, D.Sc., Sc.D., LL.D., F.R.S.

PRESIDENT OF THE ASSOCIATION.

The British Association assembles for the third time in Aberdeen—under the happiest of auspices. It is good that we are meeting in Scotland, for the Association has a tradition that its Scottish meetings are wholly successful. It is good that we are meeting in the sympathetic atmosphere of a university city, surrounded not only by beautiful and venerable buildings, but also by buildings in which scientific knowledge is being industriously and successfully accumulated. And it is especially good that Aberdeen is rich not only in scientific buildings but also in scientific associations. Most of us can think of some master-mind in his own subject who worked here. My own thoughts, I need hardly say, turn to James Clerk Maxwell.

Whatever our subject, there is one man who will be in our thoughts in a very special sense to-night—Sir William Hardy, whom we had hoped to see in the presidential chair this year. It was not to be, and his early death, while still in the fulness of his powers, casts a shadow in the minds of all of us. We all know of his distinguished work in pure science, and his equally valuable achievements in applied science. I will not try to pay tribute to these, since it has been arranged that others, better qualified than myself, shall do so in a special memorial lecture. Perhaps, however, I may be permitted to bear testimony to the personal qualities of one whom I was proud to call a friend for a large part of my life, and a colleague for many years. Inside the Council room, his proposals were always acute, often highly original, and invariably worthy of careful consideration; outside, his big personality and wide range of interests made him the most charming and versatile of friends.

And now I must turn to the subject on which I have specially undertaken to speak—the new world-picture presented to us by modern physics. It is a full half-century since this chair was last occupied by a theoretical physicist in the person of the late Lord Rayleigh. In that interval the main edifice of science has grown almost beyond recognition, increasing in extent, dignity and beauty, as whole armies of labourers have patiently added wing after wing, story upon story, and pinnacle to pinnacle. Yet the theoretical physicist must admit that his own department looks like nothing so much as a building which has been brought down in ruins by a succession of earthquake shocks.

The earthquake shocks were, of course, new facts of observation, and the building fell because it was not built on the solid rock of ascertained fact, but on the ever-shifting sands of conjecture and speculation. Indeed it was little more than a museum of models, which had accumulated because the old-fashioned physicist had a passion for trying to liken the ingredients of Nature to familiar objects such as billiard-balls, jellies and spinning tops. While he believed and proclaimed that Nature had existed and gone her way for countless aeons before man came to spy on her, he assumed that the latest newcomer on the scene, the mind which could never get outside itself and its own sensations, would find things within its limited experience to explain what had existed from all eternity. It was expecting too much of Nature, as the ruin of our building has shown. She is not so accommodating as this to the limitations of the human mind; her truths can only be made comprehensible in the form of parables.

Yet no parable can remain true throughout its whole range to the facts it is trying to explain. Somewhere or other it must be too wide or too narrow, so that ' the truth, the whole truth, and nothing but the truth ' is not to be conveyed by parables. The fundamental mistake of the old-fashioned physicist was that he failed to distinguish between the half-truths of parables and the literal truth.

Perhaps his mistake was pardonable, perhaps it was even natural. Modern psychologists make great use of what they describe as ' word-association.' They shoot a word at you, and ask you to reply immediately with the first idea it evokes in your uncontrolled mind. If the psychologist says ' wave,' the boy-scout will probably say ' flag,' while the sailor may say ' sea,' the musician ' sound,' the engineer ' compression,' and the mathematician ' sine ' or ' cosine.' Now the crux of the situation is that the number of people who will give this last response is very small. Our remote ancestors did not survive in the struggle for existence by pondering over sines and cosines, but by devising ways of killing other animals without being killed themselves. As a consequence, the brains we have inherited

from them take more kindly to the concrete facts of everyday life than to abstract concepts ; to particulars rather than to universals. Every child, when first it begins to learn algebra, asks in despair 'But what are x, y and z?' and is satisfied when, and only when, it has been told that they are numbers of apples or pears or bananas or something such. In the same way, the old-fashioned physicist could not rest content with x, y and z, but was always trying to express them in terms of apples or pears or bananas. Yet a simple argument will show that he can never get beyond x, y and z.

Physical science obtains its knowledge of the external world by a series of exact measurements, or, more precisely, by comparisons of measurements. Typical of its knowledge is the statement that the line $H\alpha$ in the hydrogen spectrum has a wave-length of so many centimetres. This is meaningless until we know what a centimetre is. The moment we are told that it is a certain fraction of the earth's radius, or of the length of a bar of platinum, or a certain multiple of the wave-length of a line in the cadmium spectrum, our knowledge becomes real, but at that same moment it also becomes purely numerical. Our minds can only be acquainted with things inside themselves—never with things outside. Thus we can never know the essential nature of anything, such as a centimetre or a wave-length, which exists in that mysterious world outside ourselves to which our minds can never penetrate ; but we can know the numerical ratio of two quantities of similar nature, no matter how incomprehensible they may both be individually.

For this reason, our knowledge of the external world must always consist of numbers, and our picture of the universe—the synthesis of our knowledge—must necessarily be mathematical in form. All the concrete details of the picture, the apples and pears and bananas, the ether and atoms and electrons, are mere clothing that we ourselves drape over our mathematical symbols—they do not belong to Nature, but to the parables by which we try to make Nature comprehensible. It was, I think, Kronecker who said that in arithmetic God made the integers and man made the rest ; in the same spirit, we may add that in physics God made the mathematics and man made the rest.

The modern physicist does not use this language, but he accepts its implications, and divides the concepts of physics into observables and unobservables. In brief, the observables embody facts of observation, and so are purely numerical or mathematical in their content ; the unobservables are the pictorial details of the parables.

The physicist wants to make his new edifice earthquake-proof—immune to the shock of new observations—and so builds only on the solid rock, and with the solid bricks, of ascertained fact. Thus he builds only with observables, and his whole edifice is one of

mathematics and mathematical formulæ—all else is man-made decoration.

For instance, when the undulatory theory had made it clear that light was of the nature of waves, the scientists of the day elaborated this by saying that light consisted of waves in a rigid, homogeneous ether which filled all space. The whole content of ascertained fact in this description is the one word 'wave' in its strictly mathematical sense; all the rest is pictorial detail, introduced to help out the inherited limitations of our minds.

Then scientists took the pictorial details of the parable literally, and so fell into error. For instance, light-waves travel in space and time jointly, but by filling space and space alone with ether, the parable seemed to make a clear-cut distinction between space and time. It even suggested that they could be separated out in practice—by performing a Michelson-Morley experiment. Yet, as we all know, the experiment when performed only showed that such a separation is impossible; the space and time of the parable are found not to be true to the facts—they are revealed as mere stage-scenery. Neither is found to exist in its own right, but only as a way of cutting up something more comprehensive—the space-time continuum.

Thus we find that space and time cannot be classified as realities of nature, and the generalised theory of relativity shows that the same is true of their product, the space-time continuum. This can be crumpled and twisted and warped as much as we please without becoming one whit less true to nature—which, of course, can only mean that it is not itself part of nature.

In this way space and time, and also their space-time product, fall into their places as mere mental frameworks of our own construction. They are of course very important frameworks, being nothing less than the frameworks along which our minds receive their whole knowledge of the outer world. This knowledge comes to our minds in the form of messages passed on from our senses; these in turn have received them as impacts or transfers of electromagnetic momentum or energy. Now Clerk Maxwell showed that electromagnetic activity of all kinds could be depicted perfectly as travelling in space and time—this was the essential content of his electromagnetic theory of light. Thus space and time are of preponderating importance to our minds as the media through which the messages from the outer world enter the 'gateways of knowledge,' our senses, and in terms of which they are classified. Just as the messages which enter a telephone exchange are classified by the wires along which they arrive, so the messages which strike our senses are classified by their arrival along the space-time framework.

Physical science, assuming that each message must have had a

starting-point, postulated the existence of 'matter' to provide such starting-points. But the existence of this matter was a pure hypothesis; and matter is in actual fact as unobservable as the ether, Newtonian force, and other unobservables which have vanished from science. Early science not only assumed matter to exist, but further pictured it as existing in space and time. Again this assumption had no adequate justification; for there is clearly no reason why the whole material universe should be restricted to the narrow framework along which messages strike our senses. To illustrate by an analogy, the earthquake waves which damage our houses travel along the surface of the ground, but we have no right to assume that they originate in the surface of the ground; we know, on the contrary, that they originate deep down in the earth's interior.

The Newtonian mechanics, however, having endowed space and time with real objective existences, assumed that the whole universe existed within the limits of space and time. Even more characteristic of it was the doctrine of 'mechanistic determinism,' which could be evolved from it by strictly logical processes. This reduced the whole physical universe to a vast machine in which each cog, shaft, and thrust bar could only transmit what it received, and wait for what was to come next. When it was found that the human body consisted of nothing beyond commonplace atoms and molecules, the human race also seemed to be reduced to cogs in the wheel, and in face of the inexorable movements of the machine, human effort, initiative, and ambition seemed to become meaningless illusions. Our minds were left with no more power or initiative than a sensitised cinematograph film; they could only register what was impressed on them from an outer world over which they had no control.

Theoretical physics is no longer concerned to study the Newtonian universe which it once believed to exist in its own right in space and time. It merely sets before itself the modest task of reducing to law and order the impressions that the universe makes on our senses. It is not concerned with what lies beyond the gateways of knowledge, but with what enters through the gateways of knowledge. It is concerned with appearances rather than reality, so that its task resembles that of the cartographer or map-maker rather than that of the geologist or mining engineer.

Now the cartographer knows that a map may be drawn in many ways, or, as he would himself say, many kinds of projection are available. Each one has its merits, but it is impossible to find all the merits we might reasonably desire combined in one single map. It is reasonable to demand that each bit of territory should look its proper shape on the map; also that each should look its proper

relative size. Yet even these very reasonable requirements cannot usually be satisfied in a single map ; the only exception is when the map is to contain only a small part of the whole surface of the globe. In this case, and this only, all the qualities we want can be combined in a single map, so that we simply ask for a map of the county of Surrey without specifying whether it is to be a Mercator's or orthographic or conic projection, or what not.

All this has its exact counterpart in the map-making task of the physicist. The Newtonian mechanics was like the map of Surrey, because it dealt only with a small fraction of the universe. It was concerned with the motions and changes of medium-sized objects—objects comparable in size with the human body—and for these it was able to provide a perfect map which combined in one picture all the qualities we could reasonably demand. But the inconceivably great and the inconceivably small were equally beyond its ken. As soon as science pushed out—to the cosmos as a whole in one direction and to sub-atomic phenomena in the other—the deficiencies of the Newtonian mechanics became manifest. And no modification of the Newtonian map was able to provide the two qualities which this map had itself encouraged us to expect—a materialism which exhibited the universe as constructed of matter lying within the framework of space and time, and a determinism which provided an answer to the question ' What is going to happen next ? '

When geography cannot combine all the qualities we want in a single map, it provides us with more than one map. Theoretical physics has done the same, providing us with two maps which are commonly known as the particle-picture and the wave-picture.

The particle-picture is a materialistic picture which caters for those who wish to see their universe mapped out as matter existing in space and time. The wave-picture is a determinist picture which caters for those who ask the question ' What is going to happen next ? ' It is perhaps better to speak of these two pictures as the particle-parable and the wave-parable. For this is what they really are, and the nomenclature warns us in advance not to be surprised at inconsistencies and contradictions.

Let me remind you, as briefly as possible, how this pair of pictures or parables have come to be in existence side by side.

The particle-parable, which was first in the field, told us that the material universe consists of particles existing in space and time. It was created by the labours of chemists and experimental physicists, working on the basis provided by the classical physics. Its time of testing came in 1913, when Bohr tried to find out whether the two particles of the hydrogen atom could possibly produce the highly complicated spectrum of hydrogen by their motion. He found a type of motion which could produce this spectrum down to its

minutest details, but the motion was quite inconsistent with the mechanistic determinism of the Newtonian mechanics. The electron did not move continuously through space and time, but jumped, and its jumps were not governed by the laws of mechanics, but to all appearance, as Einstein showed more fully four years later, by the laws of probability. Of 1000 identical atoms, 100 might make the jump, while the other 900 would not. Before the jumps occurred, there was nothing to show which atoms were going to jump. Thus the particle-picture conspicuously failed to provide an answer to the question ' What will happen next ? '

Bohr's concepts were revolutionary, but it was soon found they were not revolutionary enough, for they failed to explain more complicated spectra, as well as certain other phenomena.

Then Heisenberg showed that the hydrogen spectrum—and, as we now believe, all other spectra as well—could be explained by the motion of something which was rather like an electron, but did not move in space and time. Its position was not specified by the usual co-ordinates x, y, z of co-ordinate geometry, but by the mathematical abstraction known as a matrix. His ideas were rather too abstract even for mathematicians, the majority of whom had quite forgotten what matrices were. It seemed likely that Heisenberg had unravelled the secret of the structure of matter, and yet his solution was so far removed from the concepts of ordinary life that another parable had to be invented to make it comprehensible.

The wave-parable serves this purpose ; it does not describe the universe as a collection of particles but as a system of waves. The universe is no longer a deluge of shot from a battery of machine-guns, but a stormy sea with the sea taken away and only the abstract quality of storminess left—or the grin of the Cheshire cat if we can think of a grin as undulatory. This parable was not devised by Heisenberg, but by de Broglie and Schrodinger. At first they thought their waves merely provided a superior model of an ordinary electron ; later it was established that they were a sort of parable to explain Heisenberg's pseudo-electron.

Now the pseudo-electron of Heisenberg did not claim to account for the spectrum emitted by a single atom of gas, which is something entirely beyond our knowledge or experience, but only that emitted by a whole assembly of similar atoms ; it was not a picture of one electron in one atom, but of all the electrons in all the atoms.

In the same way the waves of the wave-parable do not picture individual electrons, but a community of electrons—a crowd—as for instance the electrons whose motion constitutes a current of electricity.

In this particular instance the waves can be represented as travelling through ordinary space. Except for travelling at a different

speed, they are very like the waves by which Maxwell described the flow of radiation through space, so that matter and radiation are much more like one another in the new physics than they were in the old.

In other cases, ordinary time and space do not provide an adequate canvas for the wave-picture. The wave-picture of two currents of electricity, or even of two electrons moving independently, needs a larger canvas—six dimensions of space and one of time. There can be no logical justification for identifying any particular three of these six dimensions with ordinary space, so that we must regard the wave-picture as lying entirely outside space. The whole picture, and the manifold dimensions of space in which it is drawn, become pure mental constructs—diagrams and frameworks we make for ourselves to help us understand phenomena.

In this way we have the two co-existent pictures—the particle-picture for the materialist, and the wave-picture for the determinist. When the cartographer has to make two distinct maps to exhibit the geography of, say, North America, he is able to explain why two maps are necessary, and can also tell us the relation between the two—he can show us how to transform one into the other. He will tell us, for instance, that he needs two maps simply because he is restricted to flat surfaces—pieces of paper. Give him a sphere instead, and he can show us North America, perfectly and completely, on a single map.

The physicist has not yet found anything corresponding to this sphere ; when, if ever, he does, the particle-picture and the wave-picture will be merged into a single new picture. At present some kink in our minds, or perhaps merely some ingrained habit of thought, prevents our understanding the universe as a consistent whole—just as the ingrained habits of thought of a ' flat-earther ' prevent his understanding North America as a consistent whole. Yet, although physics has so far failed to explain why two pictures are necessary, it is, nevertheless, able to explain the relation between the particle-picture and the wave-picture in perfectly comprehensible terms.

The central feature of the particle-picture is the atomicity which is found in the structure of matter. But this atomicity is only one expression of a fundamental coarse-grainedness which pervades the whole of nature. It crops up again in the fact that energy can only be transferred by whole quanta. Because of this, the tools with which we study nature are themselves coarse-grained ; we have only blunt probes at our disposal, and so can never acquire perfectly precise knowledge of nature. Just as, in astronomy, the grain of our photographic plates prevents our ever fixing the position of a star with absolute precision, so in physics we can never say that an electron is here, at this precise spot, and is moving at just such and such a

speed. The best we can do with our blunt probes is to represent the position of the electron by a smear, and its motion by a moving smear which will get more and more blurred as time progresses. Unless we check the growth of our smear by taking new observations, it will end by spreading through the whole of space.

Now the waves of an electron or other piece of matter are simply a picture of just such a smear. Where the waves are intense, the smear is black, and conversely. The nature of the smear—whether it consists of printer's ink, or, as was at one time thought, of electricity—is of no importance; this is mere pictorial detail. All that is essential is the relative blackness of the smear at different places—a ratio of numbers which measures the relative chance of electrons being at different points of space.

The relation between the wave-picture and the particle-picture may be summed up thus: the more stormy the waves at any point in the wave-picture, the more likely we are to find a particle at that point in the particle-picture. Yet, if the particles really existed as points, and the waves depicted the chances of their existing at different points of space—as Maxwell's law does for the molecules of a gas—then the gas would emit a continuous spectrum instead of the line-spectrum that is actually observed. Thus we had better put our statement in the form that the electron is not a point-particle, but that if we insist on picturing it as such, then the waves indicate the relative proprieties of picturing it as existing at the different points of space. But propriety relative to what?

The answer is—relative to our own knowledge. If we know nothing about an electron except that it exists, all places are equally likely for it, so that its waves are uniformly spread through the whole of space. By experiment after experiment we can restrict the extent of its waves, but we can never reduce them to a point, or indeed below a certain minimum; the coarse-grainedness of our probes prevents that. There is always a finite region of waves left. And the waves which are left depict our knowledge precisely and exactly; we may say that they are waves of knowledge—or, perhaps even better still, waves of imperfections of knowledge—of the position of the electron.

And now we come to the central and most surprising fact of the whole situation. I agree that it is still too early, and the situation is still too obscure, for us fully to assess its importance, but, as I see it, it seems likely to lead to radical changes in our views not only of the universe but even more of ourselves. Let us remember that we are dealing with a system of waves which depict in a graphic form our knowledge of the constituents of the universe. The central fact is this: the wave-parable does not tell us that these waves depict our knowledge of nature, but that they are nature itself.

If we ask the new physics to specify an electron for us, it does not give us a mathematical specification of an objective electron, but rather retorts with the question : 'How much do you know about the electron in question ?' We state all we know, and then comes the surprising reply, 'That is the electron.' The electron exists only in our minds—what exists beyond, and where, to put the idea of an electron into our minds we do not know. The new physics can provide us with wave-pictures depicting electrons about which we have varying amounts of knowledge, ranging from nothing at all to the maximum we can know with the blunt probes at our command, but the electron which exists apart from our study of it is quite beyond its purview.

Let me try and put this in another way. The old physics imagined it was studying an objective nature which had its own existence independently of the mind which perceived it—which, indeed, had existed from all eternity whether it was perceived or not. It would have gone on imagining this to this day, had the electron observed by the physicists behaved as on this supposition it ought to have done.

But it did not so behave, and this led to the birth of the new physics, with its general thesis that the nature we study does not consist so much of something we perceive as of our perceptions ; it is not the object of the subject-object relation, but the relation itself. There is, in fact, no clear-cut division between the subject and object ; they form an indivisible whole which now becomes nature. This thesis finds its final expression in the wave-parable, which tells us that nature consists of waves and that these are of the general quality of waves of knowledge, or of absence of knowledge, in our own minds.

Let me digress to remind you that if ever we are to know the true nature of waves, these waves must consist of something we already have in our own minds. Now knowledge and absence of knowledge satisfy this criterion as few other things could ; waves in an ether, for instance, emphatically did not. It may seem strange, and almost too good to be true, that nature should in the last resort consist of something we can really understand ; but there is always the simple solution available that the external world is essentially of the same nature as mental ideas.

At best this may seem very academic and up in the air—at the worst it may seem stupid and even obvious. I agree that it would be so, were it not for the one outstanding fact that observation supports the wave-picture of the new physics whole-heartedly and without hesitation. Whenever the particle-picture and the wave-picture have come into conflict, observation has discredited the particle-picture and supported the wave-picture—not merely, be it

noted, as a picture of our knowledge of nature, but as a picture of nature itself. The particle-parable is useful as a concession to the materialistic habits of thought which have become ingrained in our minds, but it can no longer claim to fit the facts, and, so far as we can at present see, the truth about nature must lie very near to the wave-parable.

Let me digress again to remind you of two simple instances of such conflicts and of the verdicts which observation has pronounced upon them.

A shower of parallel-moving electrons forms in effect an electric current. Let us shoot such a shower of electrons at a thin film of metal, as your own Prof. G. P. Thomson did. The particle-parable compares it to a shower of hailstones falling on a crowd of umbrellas; we expect the electrons to get through somehow or anyhow and come out on the other side as a disordered mob. But the wave-parable tells us that the shower of electrons is a train of waves. It must retain its wave-formation, not only in passing through the film, but also when it emerges on the other side. And this is what actually happens: it comes out and forms a wave-pattern which can be predicted—completely and perfectly—from its wave-picture before it entered the film.

Next let us shoot our shower of electrons against the barrier formed by an adverse electro-motive force. If the electrons of the shower have a uniform energy of ten volts each, let us throw them against an adverse potential difference of a million volts. According to the particle-parable, it is like throwing a handful of shot up into the air; they will all fall back to earth in time—the conservation of energy will see to that. But the wave-parable again sees our shower of electrons as a train of waves—like a beam of light—and sees the potential barrier as an obstructing layer—like a dirty window pane. The wave-parable tells us that this will check, but not entirely stop, our beam of electrons. It even shows us how to calculate what fraction will get through. And just this fraction, in actual fact, does get through; a certain number of ten-volt electrons surmount the potential barrier of a million volts—as though a few of the shot thrown lightly up from our hands were to surmount the earth's gravitational field and wander off into space. The phenomenon appears to be in flat contradiction to the law of conservation of energy, but we must remember that waves of knowledge are not likely to own allegiance to this law.

A further problem arises out of this experiment. Of the millions of electrons of the original shower, which particular electrons will get through the obstacle? Is it those who get off the mark first, or those with the highest turn of speed, or what? What little extra have they that the others haven't got?

It seems to be nothing more than pure good luck. We know of no way of increasing the chances of individual electrons; each just takes its turn with the rest. It is a concept with which science has been familiar ever since Rutherford and Soddy gave us the law of spontaneous disintegration of radioactive substances—of a million atoms ten broke up every year, and no help we could give to a selected ten would cause fate to select them rather than the ten of her own choosing. It was the same with Bohr's model of the atom; Einstein found that without the caprices of fate it was impossible to explain the ordinary spectrum of a hot body; call on fate, and we at once obtained Planck's formula, which agrees exactly with observation.

From the dawn of human history, man has been wont to attribute the results of his own incompetence to the interference of a malign fate. The particle-picture seems to make fate even more powerful and more all-pervading than ever before; she not only has her finger in human affairs, but also in every atom in the universe. The new physics has got rid of mechanistic determinism, but only at the price of getting rid of the uniformity of nature as well!

I do not suppose that any serious scientist feels that such a statement must be accepted as final; certainly I do not. I think the analogy of the beam of light falling on the dirty window-pane will show us the fallacy of it.

Heisenberg's mathematical equation shows that the energy of a beam of light must always be an integral number of quanta. We have observational evidence of this in the photoelectric effect, in which atoms always suffer damage by whole quanta.

Now this is often stated in parable form. The parable tells us that light consists of discrete light-particles, called photons, each carrying a single quantum of energy. A beam of light becomes a shower of photons moving through space like the bullets from a machine-gun; it is easy to see why they necessarily do damage by whole quanta.

When a shower of photons falls on a dirty window-pane, some of the photons are captured by the dirt, while the rest escape capture and get through. And again the question arises: How are the lucky photons singled out? The obvious superficial answer is a wave of the hand towards Fortune's wheel; it is the same answer that Newton gave when he spoke of his 'corpuscles of light' experiencing alternating fits of transmission and reflection. But we readily see that such an answer is superficial.

Our balance at the bank always consists of an integral number of pence, but it does not follow that it is a pile of bronze pennies. A child may, however, picture it as so being, and ask his father what determines which particular pennies go to pay the rent. The father may answer 'Mere chance'—a foolish answer, but no more foolish

than the question. Our question as to what determines which photons get through is, I think, of a similar kind, and if Nature seems to answer ' Mere chance,' she is merely answering us according to our folly. A parable which replaces radiation by identifiable photons can find nothing but the finger of fate to separate the sheep from the goats. But the finger of fate, like the photons themselves, is mere pictorial detail. As soon as we abandon our picture of radiation as a shower of photons, there is no chance but complete determinism in its flow. And the same is, I think, true when the particle-photons are replaced by particle-electrons.

We know that every electric current must transfer electricity by complete electron-units, but this does not entitle us to replace an electric current by a shower of identifiable electron-particles. Indeed the exclusion-principle of Pauli, which is in full agreement with observation, definitely forbids our doing so. When the red and white balls collide on a billiard table, red may go to the right and white to the left. The collision of two electrons A and B is governed by similar laws of energy and momentum, so that we might expect to be able to say that A goes to the right, and B to the left or *vice-versa*. Actually we must say no such thing, because we have no right to identify the two electrons which emerge from the collision with the two that went in. It is as though A and B had temporarily combined into a single drop of electric fluid, which had subsequently broken up into two new electrons, C, D. We can only say that after the collision C will go to the right, and D to the left. If we are asked which way A will go, the true answer is that by then A will no longer exist. The superficial answer is that it is a pure toss-up. But the toss-up is not in nature, but in our own minds ; it is an even chance whether we choose to identify C with A or with B.

Thus the indeterminism of the particle-picture seems to reside in our own minds rather than in nature. In any case this picture is imperfect, since it fails to represent the facts of observation. The wave-picture, which observation confirms in every known experiment, exhibits a complete determinism.

Again we may begin to feel that the new physics is little better than the old—that it has merely replaced one determinism by another. It has ; but there is all the difference in the world between the two determinisms. For in the old physics the perceiving mind was a spectator ; in the new it is an actor. Nature no longer forms a closed system detached from the perceiving mind ; the perceiver and perceived are interacting parts of a single system. The nature depicted by the wave-picture in some way embraces our minds as well as inanimate matter. Things still change solely as they are compelled, but it no longer seems impossible that part of the compulsion may originate in our own minds.

Even the inadequate particle-picture told us something very similar in its own roundabout stammering way. At first it seemed to be telling us of a nature distinct from our minds, which moved as directed by throws of the dice, and then it transpired that the dice were thrown by our own minds. Our minds enter into both pictures, although in somewhat different capacities. In the particle-picture the mind merely decides under what conventions the map is to be drawn ; in the wave-picture it perceives and observes and draws the map. We should notice, however, that the mind enters both pictures only in its capacity as a receptacle—never as an emitter.

The determinism which appears in the new physics is one of waves, and so, in the last resort, of knowledge. Where we are not ourselves concerned, we can say that event follows event ; where we are concerned, only that knowledge follows knowledge. And even this knowledge is one only of probabilities and not of certainties ; it is at best a smeared picture of the clear-cut reality which we believe to lie beneath. And just because of this, it is impossible to decide whether the determinism of the wave-picture originates in the underlying reality or not—Can our minds change what is happening in reality, or can they only make it look different to us by changing our angle of vision ? We do not know, and as I do not see how we can ever find out, my own opinion is that the problem of free-will will continue to provide material for fruitless discussion until the end of eternity.

The contribution of the new physics to this problem is not that it has given a decision on a long-debated question, but that it has reopened a door which the old physics had seemed to slam and bolt. We have an intuitive belief that we can choose our lunch from the menu or abstain from housebreaking or murder ; and that by our own volition we can develop our freedom to choose. We may, of course, be wrong. The old physics seemed to tell us that we were, and that our imagined freedom was all an illusion ; the new physics tells us it may not be.

The old physics showed us a universe which looked more like a prison than a dwelling-place. The new physics shows us a building which is certainly more spacious, although its interior doors may be either open or locked—we cannot say. But we begin to suspect it may give us room for such freedom as we have always believed we possessed ; it seems possible at least that in it we can mould events to our desire, and live lives of emotion, intellect, and endeavour. It looks as though it might form a suitable dwelling-place for man, and not a mere shelter for brutes.

The new physics obviously carries many philosophical implications, but these are not easy to describe in words. They cannot be

summed up in the crisp, snappy sentences beloved of scientific journalism, such as that materialism is dead, or that matter is no more. The situation is rather that both materialism and matter need to be redefined in the light of our new knowledge. When this has been done, the materialist must decide for himself whether the only kind of materialism which science now permits can be suitably labelled materialism, and whether what remains of matter should be labelled as matter or as something else ; it is mainly a question of terminology.

What remains is in any case very different from the full-blooded matter and the forbidding materialism of the Victorian scientist. His objective and material universe is proved to consist of little more than constructs of our own minds. To this extent, then, modern physics has moved in the direction of philosophic idealism. Mind and matter, if not proved to be of similar nature, are at least found to be ingredients of one single system. There is no longer room for the kind of dualism which has haunted philosophy since the days of Descartes.

This brings us at once face to face with the fundamental difficulty which confronts every form of philosophical idealism. If the nature we study consists so largely of our own mental constructs, why do our many minds all construct one and the same nature ? Why, in brief, do we all see the same sun, moon and stars ?

I would suggest that physics itself may provide a possible although very conjectural clue. The old particle-picture which lay within the limits of space and time, broke matter up into a crowd of distinct particles, and radiation into a shower of distinct photons. The newer and more accurate wave-picture, which transcends the framework of space and time, recombines the photons into a single beam of light, and the shower of parallel-moving electrons into a continuous electric current. Atomicity and division into individual existences are fundamental in the restricted space-time picture, but disappear in the wider, and as far as we know more truthful, picture which transcends space and time. In this, atomicity is replaced by what General Smuts would describe as 'holism'—the photons are no longer distinct individuals each going its own way, but members of a single organisation or whole—a beam of light. The same is true, *mutatis mutandis*, of the electrons of a parallel-moving shower. The biologists are beginning to tell us, although not very unanimously, that the same may be true of the cells of our bodies. And is it not conceivable that what is true of the objects perceived may be true also of the perceiving minds ? When we view ourselves in space and time we are quite obviously distinct individuals ; when we pass beyond space and time we may perhaps form ingredients of a continuous stream of life. It is only a step from this to a solution of

the problem which would have commended itself to many philosophers, from Plato to Berkeley, and is, I think, directly in line with the new world-picture of modern physics.

I have left but little time to discuss affairs of a more concrete nature. We meet in a year which has to some extent seen science arraigned before the bar of public opinion; there are many who attribute most of our present national woes—including unemployment in industry and the danger of war—to the recent rapid advance in scientific knowledge.

Even if their most lurid suspicions were justified, it is not clear what we could do. For it is obvious that the country which called a halt to scientific progress would soon fall behind in every other respect as well—in its industry, in its economic position, in its naval and military defences, and, not least important, in its culture. Those who sigh for an Arcadia in which all machinery would be scrapped and all invention proclaimed a crime, as it was in Erewhon, forget that the Erewhonians had neither to compete with highly organised scientific competitors for the trade of the world nor to protect themselves against possible bomb-dropping, blockade or invasion.

But can we admit that the suspicions of our critics are justified? If science has made the attack more deadly in war, it has also made the defence more efficient in the long run; it shows no partiality in the age-long race between weapons of attack and defence. This being so, it would, I think, be hard to maintain in cold blood that its activities are likely to make wars either more frequent or more prolonged. It is at least arguable that the more deadly a war is likely to be, the less likely it is to occur.

Still it may occur. We cannot ignore the tragic fact that, as our President of two years ago told us, science has given man control over Nature before he has gained control over himself. The tragedy does not lie in man's scientific control over Nature but in his absence of moral control over himself. This is only one chapter of a long story—human nature changes very slowly, and so for ever lags behind human knowledge, which accumulates very rapidly. The plays of Aeschylus and Sophocles still thrill us with their vital human interest, but the scientific writings of Aristarchus and Ptolemy are dead—mere historical curiosities which leave us cold. Scientific knowledge is transmitted from one generation to another, while acquired characteristics are not. Thus, in respect of knowledge, each generation stands on the shoulders of its predecessor, but in respect of human nature, both stand on the same ground.

These are hard facts which we cannot hope to alter, and which —we may as well admit—may wreck civilisation. If there is an avenue of escape, it does not, as I see it, lie in the direction of less

science, but of more science—psychology, which holds out hopes that, for the first time in his long history, man may be enabled to obey the command 'Know thyself'; to which I, for one, would like to see adjoined a morality and, if possible, even a religion, consistent with our new psychological knowledge and the established facts of science; scientific and constructive measures of eugenics and birth control; scientific research in agriculture and industry, sufficient at least to defeat the gloomy prophecies of Malthus and enable ever larger populations to live in comfort and contentment on the same limited area of land. In such ways we may hope to restrain the pressure of population and the urge for expansion which, to my mind, are far more likely to drive the people of a nation to war than the knowledge that they—and also the enemies they will have to fight—are armed with the deadliest weapons which science can devise.

This last brings us to the thorny problem of economic depression and unemployment. No doubt a large part of this results from the war, national rivalries, tariff barriers, and various causes which have nothing to do with science, but a residue must be traced to scientific research; this produces labour-saving devices which in times of depression are only too likely to be welcomed as wage-saving devices and to put men out of work. The scientific Robot in *Punch's* cartoon boasted that he could do the work of 100 men, but gave no answer to the question—'Who will find work for the displaced 99?' He might, I think, have answered—'The pure scientist, in part at least.' For scientific research has two products of industrial importance—the labour-saving inventions which displace labour, and the more fundamental discoveries which originate as pure science, but may ultimately lead to new trades and new popular demands providing employment for vast armies of labour.

Both are rich gifts from science to the community. The labour-saving devices lead to emancipation from soul-destroying toil and routine work, to greater leisure and better opportunities for its enjoyment. The new inventions add to the comfort and pleasure, health and wealth of the community. If a perfect balance could be maintained between the two, there would be employment for all, with a continual increase in the comfort and dignity of life. But, as I see it, troubles are bound to arise if the balance is not maintained, and a steady flow of labour-saving devices with no accompanying steady flow of new industries to absorb the labour they displace, cannot but lead to unemployment and chaos in the field of labour. At present we have a want of balance resulting in unemployment, so that our great need at the moment is for industry-making discoveries. Let us remember Faraday's electromagnetic induction, Maxwell's Hertzian waves, and the Otto cycle—each of which has provided

employment for millions of men. And, although it is an old story, let us also remember that the economic value of the work of one scientist alone, Edison, has been estimated at three thousand million pounds.

Unhappily, no amount of planning can arrange a perfect balance. For as the wind bloweth where it listeth, so no one can control the direction in which science will advance ; the investigator in pure science does not know himself whether his researches will result in a mere labour-saving device or a new industry. He only knows that if all science were throttled down, neither would result ; the community would become crystallised in its present state, with nothing to do but watch its population increase, and shiver as it waited for the famine, pestilence or war which must inevitably come to restore the balance between food and mouths, land and population.

Is it not better to press on in our efforts to secure more wealth and leisure and dignity of life for our own and future generations, even though we risk a glorious failure, rather than accept inglorious failure by perpetuating our present conditions, in which these advantages are the exception rather than the rule ? Shall we not risk the fate of that over-ambitious scientist Icarus, rather than resign ourselves without an effort to the fate which has befallen the bees and ants ? Such are the questions I would put to those who maintain that science is harmful to the race.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

THEORIES OF LIGHT

ADDRESS BY

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Early speculations as to how impressions were produced on the senses ascribed the sensations associated with the senses of taste and smell to the emanation of small particles of the substances involved, and ascribed the sensations associated with the sense of sound to undulations or pulses in the air. The sensations associated with the sense of sight were assumed by some philosophers to be produced in a manner similar to those belonging to the senses of taste and smell, while by others they were assumed to be produced in a manner similar to those of sound. In the first case they were assumed to be produced by emanations from the body seen, in the second case by undulations due to the body. Among the Greeks Empedocles was an exponent of the first view, while Aristotle supported the second view. It should be noted that different views were held by those who supported an emanation theory as to the nature of the emanation. Some held that the emanation consisted of small particles of matter, while others held that the emanation was something different from matter.

In the fifteenth and sixteenth centuries, when attention was being directed again to the study of natural phenomena, the two types of theory were revived. The form of the emanation theory which was adopted ultimately is that due to Newton, usually referred to as the corpuscular theory of light. In this theory light is regarded as consisting of very small particles of matter emitted by luminous bodies with the same velocity, the velocity of light. These light particles are supposed to be repelled or attracted by the molecules of material bodies according to some law depending on the distance between them. It is further assumed that the law is such that the force can change from an attraction to a repulsion or from a repulsion to an attraction, that these forces are insensible at sensible distances, that the motion of a light particle satisfies the ordinary laws of dynamics, and that, as the light particle

moves, it passes through states which have been termed 'fits of easy transmission and easy reflexion' by Newton, these states recurring periodically.

The form of the undulating theory which was adopted is due to Huygens. On this theory light consists of undulations propagated through an elastic medium which fills all space; it is assumed that the elasticity of this medium is different in different material bodies and different from its elasticity in free space, and that therefore the velocity of propagation of light in a material medium is different from its velocity of propagation in free space. It is a consequence of either theory that when all the media are isotropic $\Sigma\mu s$ along the path of a ray from one point to another point is stationary, and this relation is sufficient to give the results which are classed under the term of Geometrical Optics. The modification necessary in this result to make it applicable to the case of crystalline media was effected by Laplace, who made use of the corpuscular theory of light in his investigation and assumed that the velocity of the light particles in a crystalline medium depended on the direction. The same result was also derived from the undulatory theory.

At the end of the eighteenth century the corpuscular theory of light was the theory which was accepted generally; one of the main arguments against an undulatory theory was its failure to explain the formation of shadows. Early last century the principle of interference was put forward by Young to account for the formation of shadows on the undulatory theory, and somewhat later, though independently, Fresnel arrived at the same result. In 1816 Arago and Fresnel showed that light polarised in perpendicular planes did not interfere. It is not improbable that Fresnel had inferred already that the direction of the disturbance which constituted light was transverse to the direction of propagation, and that these experiments confirmed it, but he makes no reference to the principle of transversality in his writings for a considerable time. The earliest explicit reference to the principle I have been able to find is contained in a letter from Young to Arago written in January 1817. Young had visited Arago after the experiments had been carried out in 1816 and discussed them with him, and he appears to have been the only one who saw the importance of Fresnel's inference and who agreed with it. In his essay on diffraction (1818) Fresnel does not refer to the principle; he uses Huygens' principle and the principle of interference to obtain his results, principles which are independent of the direction of the disturbance. After the publication of his essay on diffraction, Fresnel applied his law of transversality to the phenomena of polarisation, the propagation of light in crystalline media and other problems. He obtained and verified by observation relations between the intensities of the incident, transmitted, and reflected light, when light is incident on a surface which separates two isotropic transparent media, and these relations have ever since been regarded as conditions which any adequate theory of light must satisfy. This is also true of the results he obtained for the propagation of light in crystalline media. Fresnel's

method of attack is to a great extent geometrical and independent of any hypothesis as to the nature of a medium.

The developments which had taken place in analytical mathematical methods beginning with the work of the Bernoullis on strings which led to Fourier's work and Lagrange's treatment of dynamical problems made it possible to submit the hypothesis that light is due to the vibrations of an elastic medium to a more rigorous analysis. The earliest investigation of this kind is due to Cauchy. In Cauchy's treatment the elastic medium is supposed to consist of small particles or molecules which act on each other, and the further hypothesis is made that the force between any two particles is along the line joining the two points which are taken to represent the two particles. As the same problem was discussed by Green in a more general way in 1837 it is unnecessary to refer to Cauchy's results in detail.

The hypothesis which Green made with respect to the mutual actions of portions of the elastic medium was that they possessed a work function. He investigated the form of this function and proved that when the medium is isotropic and homogeneous it involves two constants, and that, if transverse waves are propagated in the medium independently of normal waves, the velocity of propagation of normal waves must be either indefinitely great or indefinitely small. He further proved that if the elastic medium is stable the velocity of propagation of normal waves in it must be indefinitely great.

The difference between two isotropic homogeneous media is assumed to be a difference between their densities,[1] and on this assumption the relations between the amplitudes of the incident, the transmitted, and the reflected waves are obtained when waves are incident on a surface separating two such media. For waves polarised in the plane of incidence the relations are the same as Fresnel's, and for waves polarised perpendicularly to the plane of incidence the relations are very approximately the same as Fresnel's except when the index of refraction is great. The difference between Cauchy's hypothesis as to the nature of the mutual actions of the medium and Green's hypothesis has been referred to above; another important difference in their treatments is that Cauchy assumes that the direction of the disturbance in the medium is parallel to the plane of polarisation, while Green, in accordance with Fresnel's view, assumes that this direction is perpendicular to the plane of polarisation.

Green's investigation is of special interest, as it is the first where Lagrange's dynamical method is used for the treatment of a physical problem, and where the advantages of using a general dynamical principle as the basis of the argument rather than hypotheses which involve the assumption of particular modes of action are recognised.

In 1839 Green applied the same method of treatment to the investiga-

[1] The assumption that the difference between two isotropic homogeneous media is a difference in the elastic constants leads to results which do not agree with the observed facts.

tion of the propagation of waves of light in a crystalline medium. In addition to the limitation used in his previous investigations, that transverse waves can be propagated in the medium independently of normal waves, he introduces the further limitation in accordance with Fresnel's theory, that the media satisfy the condition that the directions of the transverse vibrations are always in the front of the wave. With these limitations he proves that, if the direction of a disturbance is parallel to the plane of polarisation and the medium is free from the action of any external forces, the directions of polarisation and the velocities of propagation are the same as in Fresnel's theory. In his previous investigations he had proved that in order to satisfy Fresnel's relations between the amplitudes of the incident, transmitted, and reflected waves at the surface separating two isotropic homogeneous media, the direction of a disturbance is perpendicular to the plane of polarisation. He then shows that in order to satisfy Fresnel's results for crystalline media when the direction of a disturbance is perpendicular to the plane of polarisation it is necessary to assume the existence of extraneous forces, and that, with the appropriate restrictions on these extraneous forces, the results agree with those of Fresnel's theory.

It thus appears that an elastic solid medium which is self-contained and free from external constraints will not account for the observed facts. Cauchy arrived at the same result almost simultaneously.

Various modifications of Green's elastic solid theory of light have been proposed, but none of them is satisfactory. Perhaps the most interesting is that proposed by Lord Kelvin in his Baltimore Lectures. This theory assumes that normal waves in the elastic medium are propagated with zero velocity, and to get over the difficulty, pointed out by Green, that such a medium is not stable, the medium is supposed to be attached to a boundary. Thus, although this theory gives results for the relations between the amplitudes of the incident, the transmitted, and the reflected waves at the boundary separating two isotropic media and also for the propagation of waves in crystalline media which agree with Fresnel's results, it is open to the same objection as Green's elastic solid theory which requires the intervention of extraneous forces, as the condition that the medium is attached to a boundary postulates the existence of some other medium which acts on and controls it.

Although these different investigations did not succeed in establishing a satisfactory mechanical theory of light, they were instrumental in advancing the knowledge of the subject. One important result emerged, that any theory to be satisfactory must agree with Fresnel's results, and some writers, e.g. Lorenz, based many of their investigations on Fresnel's results.

In Green's treatment of the elastic solid theory the Lagrangian function used by him is of the type which is expressed as the difference of a kinetic energy function and a potential energy function. The kinetic energy function is the sum of the squares of the velocities of the medium multiplied by the density, and, if the rate of transfer of energy due to

a source in such a medium emitting waves of one frequency is evaluated, it will be found that it is oscillatory, and this is also true when the potential energy function is of the most general type for an elastic medium. It should be observed that, just as in the case of waves of sound from a source or of waves in water, there is an actual displacement of the medium itself, e.g. in the case of waves of sound air must be supposed to be pumped in and out at the source, and this accounts for the fact that the rate of transfer of energy is oscillatory. This suggests that it should be possible to pump out portions of such a medium, and raises the question whether a medium which is subject to the laws of dynamics and which possesses a kinetic energy of this type can be an ultimate medium which will account for the phenomena of light.

The next important stage in the development of theories of light is the discovery by Faraday in 1845 that when polarised light passed through a transparent medium its plane of polarisation was rotated by the imposition of a magnetic field. In the introduction to his account of these experiments Faraday says : ' I have long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin ; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalents of power in their action. This strong persuasion extended to the powers of light, and led, on a former occasion, to many exertions, having for their object the discovery of the direct relation of light and electricity, and their mutual action in bodies subject jointly to their power ; but the results were negative. These ineffectual exertions, and many others which were never published, could not remove my strong persuasion derived from philosophical considerations ; and, therefore, I recently resumed the inquiry by experiment in a most strict and searching manner, and have at last succeeded in *magnetizing and electrifying a ray of light*.' In a footnote added subsequently Faraday says : ' Neither accepting nor rejecting the hypothesis of an aether, or the corpuscular, or any other view that may be entertained of the nature of light ; and, as far as I can see, nothing being really known of a ray of light more than of a line of magnetic or electric force, or even of a line of gravitating force, except as it and they are manifest in and by substances ; I believe that, in the experiments I describe in the paper, light has been magnetically affected.'

Almost twenty years later, in 1865, Maxwell propounded a theory of light in his memoir, *A Dynamical Theory of the Electromagnetic Field.*[2] In the introduction Maxwell states : ' We have therefore some reason to believe, from the phenomena of light and heat, that there is an aethereal medium filling space and permeating bodies, capable of being set in motion and of transmitting that motion from one part to another and of

[2] What might be termed an electric theory of light was propounded by Oersted ; in this theory light was regarded as a succession of electric sparks.

communicating that motion to gross matter so as to heat it and affect it in various ways.

'We may therefore receive, as a datum derived from a branch of science independent of that with which we have to deal, the existence of a pervading medium, of small but real density, capable of being set in motion, and of transmitting motion from one part to another with great, but not infinite, velocity.

'Hence the parts of this medium must be so connected that the motion of one part depends in some way on the motions of the rest; and at the same time these connexions must be capable of a certain kind of elastic yielding, since the communication of motion is not instantaneous, but occupies time.

'The medium is therefore capable of receiving and storing up two kinds of energy, the "actual" energy depending on the motions of its parts, and "potential" energy, consisting of the work which the medium will do in recovering from displacement in virtue of its elasticity.'

Maxwell postulates further that the all-pervading medium possesses physical characteristics of the same kind as a homogeneous isotropic dielectric, that the effect of the action of an electric force on it is the production of what he terms 'electric displacement,' which is 'a kind of elastic yielding to the action of the force similar to that which takes place in structures and machines owing to the want of perfect rigidity of the connexions.'

He shows that the application of the general equations of electrodynamics, derived from the Ampère-Faraday laws, to the case of a magnetic disturbance propagated through a non-conducting field gives the result that the only disturbances which can be so propagated are those which are transverse to the direction of propagation, and that the velocity of propagation is the velocity v, which expresses the number of electrostatic units of electricity which are contained in one electromagnetic unit.

The all-pervading medium which Maxwell postulates is a medium which possesses to some extent the physical characteristics of an elastic solid, and it is probable that his replacement of the expression for the electrokinetic energy which is obtained from Faraday's laws by an expression which gives the energy in terms of the magnetic force, was effected to make it similar to the expression for the kinetic energy function of an elastic solid. This replacement is effected by an integration by parts and neglecting the surface integral on the ground that at an indefinitely great distance the surface integral tends to zero, but this overlooks the fact that the law of variation of magnetic force with distance is not the same when the magnetic field is varying as it is when the magnetic field is steady. This does not affect Maxwell's investigation of the propagation of a magnetic disturbance, as this expression for the electrokinetic energy is not used in that investigation.

As has been seen, Faraday's view, as set forth in his 1845 paper, is different, and he explains his views in greater detail in a letter which

was published in the *Philosophical Magazine* in 1846. In this letter he states : ' The view which I am so bold as to put forth considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles and also masses of matter together. It endeavours to dismiss the aether, but not the vibration. The kind of vibration which, I believe, can alone account for the wonderful, varied, and beautiful phenomena of polarization, is not the same as that which occurs on the surface of disturbed water, or the waves of sound in gases or liquids, for the vibrations in these cases are direct, or to and from the centre of action, whereas the former are lateral. It seems to me, that the resultant of two or more lines of force is an apt condition for that action which may be considered as equivalent to a *lateral* vibration ; whereas a uniform medium like the aether does not appear apt, or more apt than air or water.

' The occurrence of a change at one end of a line of force easily suggests a consequent change at the other. The propagation of light, and therefore probably of all radiant action, occupies *time* ; and that a vibration of the line of force should account for the phenomena of radiation, it is necessary that such vibration should occupy time also.'

And again : ' The aether is assumed as pervading all bodies as well as space : in the view now set forth, it is the forces of the atomic centres which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is, that the aether presents successive parts or centres of action, and the present supposition only lines of action ; as regards matter, the difference is, that the aether lies between the particles and so carries on the vibrations, whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued.'

Faraday, like Fresnel, appears to be thinking in terms of geometrical relations, while Maxwell is seeking to construct a mechanical model whose motions will resemble those which constitute light.

Starting from Faraday's ideas, the problem of the propagation of a magnetic disturbance in free space can be approached in a direct manner. There are three vectors involved—the electric current at a point in the space, the magnetic force at the point, and the electric force at the point. The relation between the electric current and the magnetic force is given by Ampère's law,[3] and the relation between the magnetic force and the electric force is given by Faraday's law. Assuming, with Faraday, that the phenomena of light and of electricity have a common origin, Fresnel's law of transversality, that the vectors which specify the disturbance are perpendicular to the direction of propagation, will hold for the propagation of an electric or a magnetic disturbance as well as for light. These three laws are sufficient to determine the circumstances of the propagation of a magnetic disturbance in free space. It follows that for plane waves

[3] It should be noted that Ampère's law was established initially for steady electric currents ; its extension to the case where the electric currents are varying is a result of Faraday's work.

the direction of the vector j, whose time rate of increase is the electric current, at a point coincides with the direction of the electric force E at the point, and the relation between E and j is $E = 4\pi V^2 j$, where V is the velocity of propagation of a magnetic disturbance in free space. Further, if the changes which constitute the disturbance satisfy the laws of dynamics, the potential energy per unit of volume is $\frac{1}{2} Ej$—that is, $E^2/8\pi V^2$ in electromagnetic units—and, if E_1 is the same electric force in electrostatic units, the potential energy is $E_1{}^2/8\pi$; therefore $E = VE_1$, that is, the velocity of propagation is the velocity by which an electric force expressed in electrostatic units must be multiplied to convert it into electromagnetic units, or since the product of an electric charge and the electric force on it, being a mechanical force, is the same in both systems of units, the velocity of propagation is the velocity by which an electric charge expressed in electromagnetic units must be multiplied to convert it into electrostatic units.

The Lagrangian function of the changes which belong to the propagation of an electric or magnetic disturbance in free space is the difference of a kinetic energy function and a potential energy function. The potential energy function is the function given above—the kinetic energy function depends on the electromagnetic momentum and the electric current at a point; the contribution from an element in the neighbourhood of a point cannot be expressed in terms of one vector: it depends on the electric currents throughout space. On this theory the rate of transfer of energy from a source emitting waves of one frequency is steady and not oscillatory as on an elastic solid theory.

Consistently with the foregoing, the effect of material media, so far as electric and magnetic phenomena are concerned, can be represented by a distribution of electric currents and of magnetic currents throughout the space occupied by the material media. These electric current and magnetic current distributions can be supposed to be due to electric charges and to magnetic particles which are in motion, and it follows from the electrodynamical equations, when these current distributions are taken account of, that the current distributions can be represented by a distribution of electric and magnetic oscillators throughout the space occupied by the material media.

Further, the magnetic field due to a distribution of electric and magnetic currents inside a closed surface at any point outside this closed surface can be expressed in terms of the components of the electric and magnetic forces tangential to the surface—that is, any distribution of electric and magnetic currents inside a closed surface produces the same magnetic field at points outside the surface as a distribution of electric and magnetic currents on the surface which is determined by the components of the magnetic and electric forces tangential to the surface at points on it, but a knowledge of the magnetic field external to a closed surface does not determine the distribution of electric and magnetic currents inside the surface which is producing the magnetic field.

When the states of motion belonging to the electric and magnetic current distributions in the material medium are steady states of motion

the material medium is in a state of relative equilibrium, but, when an electric or magnetic disturbance is being propagated in the material medium, these steady states of motion will be disturbed and, under certain conditions, the effect of the disturbance will be to set up small oscillations about the steady states of motion ; a material can be regarded as being perfectly transparent for a disturbance whose only effect is to set up small oscillations about the steady states of motion. A condition for this is that none of the frequencies involved in the disturbance are equal to or nearly equal to any of the natural frequencies belonging to the steady states of motion.

Fresnel's relations between the amplitudes of the incident, the transmitted, and the reflected waves when a train of waves is incident on the surface separating two transparent media follow on this hypothesis, and also Fresnel's results for the propagation of waves in crystalline media. It should be noticed that on this hypothesis the electric and magnetic forces at a point in a material medium which appear in the equations are not the total electric and magnetic forces at the point, but the parts of them which are due to the disturbance.

Faraday's results for the rotation of the plane of polarisation by an imposed magnetic field when light is being propagated in a non-magnetic transparent medium follow immediately from the above hypothesis without making any additional assumptions.

Further, on the same hypothesis there will be ranges of frequencies for which a material medium is transparent, the extent of such a range will depend on the intensity of the disturbances, and between any two consecutive ranges there will be a range of frequencies for which the medium is not transparent, and the mathematical treatment of the effect of disturbances involving these frequencies will require additional hypotheses.

The theory advanced above is not a mechanical theory of light in the sense that it is possible to construct a machine whose motions will resemble the motions involved in the propagation of light. The form of the electrokinetic energy function raises the question whether all the time rates of change involved in the propagation of a magnetic disturbance can be represented by moving points, and whether every time rate of change associated with physical phenomena involves change of position in space. It may be necessary to contemplate time rates of change which do not involve change of position in space although they satisfy the laws of dynamics. In this connection it is of interest to observe that a result of Faraday's laws is that, when there are electric currents in a system of circuits which are in motion, the kinetic energy function does not contain terms which involve the product of an electric current and a velocity, a result which Maxwell verified experimentally.

A possible hypothesis is that physical phenomena are due to the interaction of time rates of change which satisfy the laws of dynamics, and the Lagrangian function in that case would be a homogeneous quadratic function of all the time rates of change. In actual cases only some of the changes are being observed, and the Lagrangian function which is obtained from the experimental evidence is a modified Lagrangian function where

the unobserved changes are supposed to be eliminated. In certain cases this function will be expressed as the difference of a kinetic energy and a potential energy function ; an important case is the case where the unobserved changes appear in the original Lagrangian function as velocities only and there are no product terms which involve a velocity belonging to the observed and a velocity belonging to the unobserved changes. There are also cases where the modified function is of this form approximately.

SECTION B.—CHEMISTRY.

PHYSICAL METHODS IN CHEMISTRY

ADDRESS BY

PROF. T. MARTIN LOWRY, C.B.E., D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

Current Events.

In reviewing the development of chemistry in this country during the past year, I must place in the forefront the political events which have turned so many of our most welcome visitors into residents. It is impossible as yet to appreciate fully the contribution thus made to the advancement of science in this country, and it would perhaps be invidious to mention any names ; but I must make an exception in order to say that in Cambridge we were just beginning to discover how great a chemist and how generous a colleague we had found in Haber, when he succumbed to a heart-weakness of long standing, less than a week after I had the privilege of presiding at his first public lecture.

I should also like to mention the holding of the 59th and 60th General Discussions of the Faraday Society in Cambridge and in Oxford respectively, since it was my privilege nearly thirty years ago to initiate the first three of these discussions, as a means of providing an appropriate environment for a modest paper of my own on 'Osmotic Pressure,' and for papers with Mr. Bousfield on the 'Hydrate Theory of Ionisation,' and on 'Liquid Water a Ternary Mixture.'

Interpenetration of Chemistry and Physics.

One of the most important features of scientific progress during the present century, and especially since the war, has been the renewal of the old intimate fellowship between chemistry and physics, which was characteristic of the earlier days, when Cavendish and Faraday were masters of both subjects and competent to make important discoveries in either. The subsequent segregation, which resulted from the growing specialisation of these two subjects of research, tended to produce chemists who were no longer competent physicists, and physicists who had little or no sympathy with chemical problems, to the great loss of both sciences. Indeed, when I was a student, the leading physical chemist was one who 'used to boast that he had never performed an

exact experiment in his life '(1) * ; and the physico-chemical theories which first attracted me to the study of chemistry were largely fallacious, since we now know that the concentration of ions in an aqueous solution cannot be deduced directly from its conductivity at different dilutions ; nor does the catalytic activity of an acid afford a direct measure of the concentration of hydrogen ions which it contains, in view of the fact that the molecules of the acid may be even more active than the ions produced from them. Even more amazing evidence of inaccurate theory was the claim made by Ostwald in 1904 (2) that the law of multiple proportions (which Sommerfeld (3) cites as one of three main arguments for the atomic theory) could be deduced without the help of the atomic hypothesis ! At the present time, however, the work of Dr. Aston in the Cavendish Laboratory, and of Professor Lennard-Jones in the Chemical Laboratory at Cambridge, may be cited as a proof of interpenetration, which is as welcome as it is undoubtedly beneficial to both laboratories. Moreover, if I may be allowed to make a more personal remark, the efficiency of my own Laboratory of Physical Chemistry at Cambridge, and the pleasure that I derive from directing it, depend largely on the fact that the workers in the laboratory consist of chemists and physicists in approximately equal numbers, so that we are equally well equipped for work in the older Physical Chemistry and in the newer Chemical Physics. Indeed, our chief need at the present time is for larger numbers of organic chemists to undertake researches in the physical chemistry of organic compounds, which do not necessarily require (as is so often feared) a knowledge of wave mechanics and a mastery of higher mathematics.

Atomic Numbers.

If I were asked to indicate the principal contribution which physics has made to the progress of chemistry during the present century, I should without hesitation point to the theory of atomic numbers, and to the galaxy of phenomena that are associated with it. We might begin, for instance, by defining the atomic number of an atom as the net positive charge of the nucleus, on the assumption that Rutherford's ' nucleus atom ' is too stable to be disintegrated by any verbal bombardment to which it may be submitted. We then pass immediately to the epoch-making conclusion that nuclear charge is more important to the chemist than atomic mass, since the chemical properties of an element depend almost exclusively on the configuration of the electronic atmosphere with which the nucleus envelops itself in the neutral atom or in the ions derived from it.

When the atomic numbers of the elements were made known, through the experiments of Moseley and others, a precise numerical basis was provided for their periodic classification. This finds its simplest expression in the Rydberg series :

$$2 \times 1^2 + 2 \times 2^2 + 2 \times 2^2 + 2 \times 3^2 + 2 \times 3^2 + 2 \times 4^2 + \ ?$$

which tells us how many electrons are required to give the configuration

* References will be found at the end of the Address.

of the inert gases. These gases owe their inertness to the extreme stability of the 'closed shells' of electrons represented by the terms of the Rydberg series. These shells are, indeed, so stable that the elements are devoid of all ordinary chemical properties, although under the stress of great excitement pairs of atoms can be wedded into diatomic molecules.

From the Rydberg series, the electronic theory of valency emerges at once, since maxima of chemical reactivity are found in those metals which can acquire the electronic configuration of an inert gas by parting with one or two surplus electrons, and in non-metals which have a like deficit in their electronic budget. Inorganic chemistry, which consists so largely of the chemistry of ions, thus finds a firm foundation in the Thomson-Kossell conception of 'electron transfer' between the atoms of unlike elements. On the other hand, the bonds by which atoms of similar elements are united in diatomic gases, and in the complex molecules of organic compounds, can be expressed by means of the Thomson-Lewis conception of 'shared electrons,' for which a physical interpretation has now been found in the spinning electron of the older quantum mechanics, and the resonance energy of the later wave-theory.

Chemical Changes in the Nucleus.

If the study of the electronic atmosphere is of primary value to the chemist in his studies of chemical reactions, it is impossible to deny that the study of the structure of the nucleus itself is of even more fundamental significance, since it is here that the atomic numbers have their origin; and, if it were not for the stability of certain selected nuclear structures, the chemist would have no atoms from which to construct his molecules, except perhaps the ultimate elements (apparently once more four in number) from which the nuclei are built. I need not now describe in detail the chemical interest which attaches to the discovery of isotopes, since this will form the basis of a subsequent discussion; but I should like to mention Oliphant's (4) separation of the isotopes of lithium, in sufficient quantities to test their behaviour towards high-speed protons and deutons, by the method of the mass-spectrograph, since this method is obviously capable of universal application, when developed on an adequate scale of magnitude. On the other hand, attention may be directed to the vast field of nuclear chemistry which has been opened up in recent years by the development of new projectiles for bombarding the nucleus. Thus the relatively clumsy α-particle, with its double positive charge, has been supplemented by the swift proton and deuton, with only a single positive charge to impede their approach to the positively charged target; and a climax has been reached by using the neutron, which can approach the nucleus without impedance by any electric charge, like aircraft attacking a battleship. It can therefore score direct hits, which are found to have a devastating effect even on the stoutest nuclei. As a result of the introduction of this new projectile, no element can now be regarded as safe from disintegration; and isotopes of short life promise in the future to become as common amongst the lighter elements as they are now amongst the spontaneously radioactive elements, which lie on the heavy side of the boundary formed by metallic lead.

Diffraction of Molecular Rays and Electrons.

Bombardment need not, however, be used only as an agent of destruction, since Dr. Fraser will tell you how gentle beams, in the form of molecular rays, travelling with the velocity of thermal agitation, instead of with velocities comparable with that of light, can be used to demonstrate the presence or absence of magnetic or electrostatic moments, to study the character of 'free radicals,' or to test the variability of 'dipole moments' with temperature; and Dr. de Laszlo will describe some applications of the method devised by Mark and Wierl for studying the structure of molecules by the orderly scattering of beams of electrons. The results thus obtained are so similar to those given by Debye's study of the diffraction of X-rays as to be almost identical.

Diffraction of X-rays.

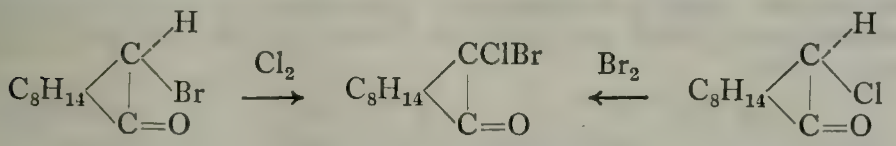
The applications of X-rays to chemistry are so numerous that I may be excused for selecting only a few examples that have interested me personally. The influence of Cox's X-ray analysis in vetoing an incorrect formula for ascorbic acid will perhaps be referred to in the joint discussion on this vitamin; but I may mention here that, in the case of another product of the same general class, Bernal was able to obtain a complete X-ray analysis by using a crystal weighing only 0·000015 mg., and was only prevented from making an exact determination of molecular weight by the Brownian movement, which prevented a precise determination of the density of the crystal by flotation—a difficulty which he suggests could be overcome with the help of a centrifuge. In a totally different field, I was during the war deeply interested in the polymorphism of ammonium nitrate, which melts at 169°, but also has transition-temperatures at 125°, 84°, 32° and −16°. The heaps of nitrate from the driers in a shell-filling factory were therefore almost always either at 84° or at 32°, on account of the arrest of cooling at these transition-points. It is fascinating now to be told that these transitions are associated with the spinning of the ions in a rigid crystal lattice. As a result of this spinning, a tetrahedral ammonium ion and a triangular nitrate ion finally acquire complete spherical symmetry, and take up the same positions as the monatomic ions of sodium and chlorine in a crystal of rock salt, so that the substance crystallises in the cubic system in the range from 125° to 169° C.

Mutarotation.

In accordance, I believe, with well-established custom, I pass on now to consider those examples of 'Physical Methods of Chemistry' with which I have been most closely concerned during a long period of years.

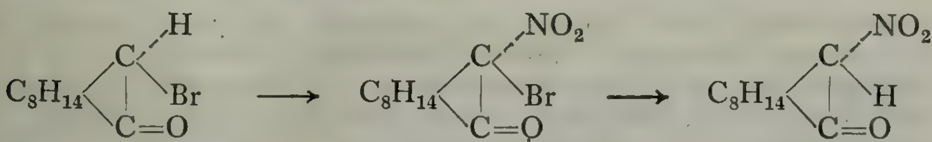
Nearly forty years ago, as a student of organic chemistry under Prof. Armstrong, I undertook my first research, on the stereochemistry of the α-derivatives of camphor. The earliest experiments (5) showed that the bromination of α-chlorocamphor and the chlorination of α-bromo-

camphor both gave an isomorphous mixture of stereoisomeric αα′- and α′α-chlorobromocamphors :



α-Bromocamphor. αα′ α′α } Chlorobromocamphor. α-Chlorocamphor.
(Isomorphous mixture.)

It was then natural to extend the research to the nitro-derivatives (6). For this purpose it was necessary not only to nitrate bromocamphor, but to brominate nitrocamphor. In this way I first encountered the nitro-compound, which has already provided a material basis for two extensive series of researches, and has not yet exhausted its utility or interest.

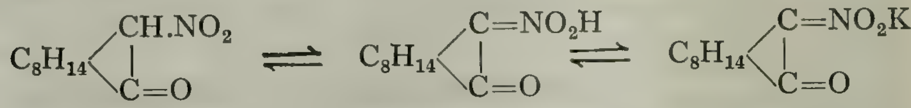


α-Bromocamphor. αα′-Bromonitrocamphor. α′-Nitrocamphor.

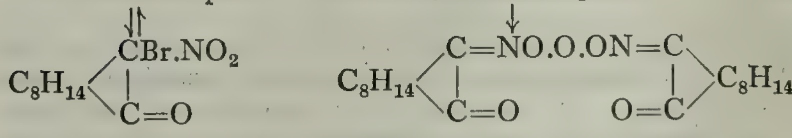
The first of a series of happy chances (7) was a measurement of the optical rotatory power of a solution of nitrocamphor in the morning, followed by a confirmatory reading in the afternoon. During the luncheon interval the rotatory power of the solution had become quite different, and I was thus presented with a novel example of the phenomenon of change of rotatory power with time, which Dubrunfaut had first observed in 1846 in a freshly prepared aqueous solution of glucose (8). This property of the reducing sugars had been variously described as birotation (8), multirotation, and paucirotation (9), according as the ratio of the initial to the final rotation was 2 : 1, greater than 1 or less than 1 ; but, since in certain solvents the *sign* as well as the magnitude of the rotation of nitrocamphor was changed, I suggested in 1899 (10) that the phenomenon should be described as *mutarotation* ; and this name has been in general use ever since.

The chemical basis of the phenomenon was disclosed by another happy accident. Wishing to know whether the change of rotatory power could be repeated when the nitrocamphor had been recovered from solution, I left a solution in benzene to evaporate on the water bath. Later in the day I examined the residue and found that it was now almost entirely insoluble in benzene. It had in fact been converted into a new compound, an anhydride formed from nitrocamphor by the loss of half a molecular proportion of water (11). An anhydride of this type could not be formed directly from nitrocamphor itself, but it could be derived easily enough from an isomeric hydroxylic form of the substance, such as that from which the salts of nitrocamphor were presumably derived. This conclusion was confirmed by the fact that the anhydride of lævorotatory nitrocamphor was, like the salts, strongly dextrorotatory.

The mutarotation of nitrocamphor, always from left towards right, could therefore be attributed to a partial conversion in solution of lævorotatory nitrocamphor into a dextrorotatory isomeride, containing an acidic hydroxyl group, which was capable of forming an anhydride as well as a series of salts.



Nitrocamphor. ψ-Nitrocamphor. Potassium salt.



Bromonitrocamphor. Anhydride of nitrocamphor.

At this stage Prof. Kipping very generously gave me a quantity of the π-bromo-derivative of α-bromonitrocamphor, from which I was able to prepare a stock of π-bromonitrocamphor. Lapworth and Kipping (12) had described this compound as trimorphous, and had recorded the crystal-constants and published drawings of two of the forms. The orthorhombic form, melting at 142°, proved to be strongly dextrorotatory when dissolved in benzene, but it became lævorotatory after a few hours. The tetragonal form, melting at 108° (which is formed as a by-product, alongside the more stable form, by rapid evaporation of a solution in chloroform), was found to be lævorotatory, but like nitrocamphor it exhibited a relatively small mutarotation from left towards right. This labile form was therefore analogous with ordinary nitrocamphor, whilst the more stable form was analogous with the still unknown pseudo-nitrocamphor, the relative stability of the two isomers having been reversed by the introduction of a halogen. The third form, for which no crystal measurements had been published, was evidently a mere mixture of these two isomers (13).

The mutarotation of the sugars in aqueous solutions had been attributed to several causes; but, when Emil Fischer (14) observed the same phenomenon during the reversible hydrolysis of the sugar-lactones, he concluded that these changes of rotatory power were due to reversible hydration, and this conclusion was very widely accepted.

$C_6H_{10}O_6$	$+ \ H_2O$	$\rightleftharpoons$	$C_6H_{12}O_7$
Gluconic lactone.			Gluconic acid.
$C_6H_{12}O_6$	$+ \ H_2O$	$\rightleftharpoons$	$C_6H_{14}O_7$
Anhydrous glucose.			Glucose hydrate.

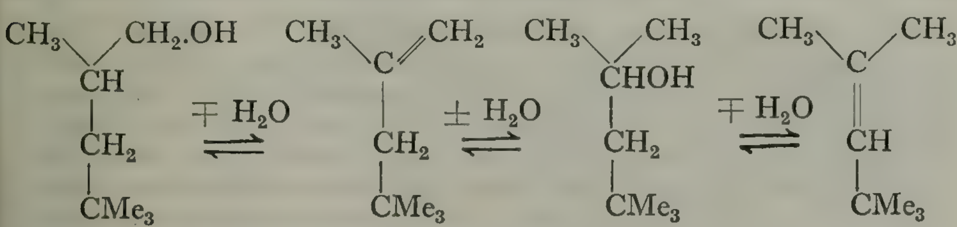
This explanation can obviously be applied to any aqueous solution in which reversible hydrolysis can take place; but it was not applicable to

nitrocamphor, which exhibited mutarotation in a large range of anhydrous solvents, but was too insoluble to be examined in aqueous solutions. Since interaction with the solvent was thus excluded, the mutarotation of nitrocamphor could only be attributed to *dissociation* or to *isomeric or polymeric change*.

At that date certain sugars had already been prepared in two isomeric forms, which exhibited mutarotation in opposite directions (15); but these changes were attributed to the complete conversion of the two sugars into a third isomeride (16). In the case of π-bromonitrocamphor, however, the product of mutarotation of the normal and pseudo forms was obviously an equilibrium-mixture of these two substances, and not a third isomeride, since, on evaporation of the solution, crystals of the normal and pseudo forms were deposited side by side. Mutarotation was therefore attributed to the *reversible isomeric change* of two isomers; and this interpretation was regarded as generally applicable to mutarotations in which interaction with the solvent could be excluded.

Dynamic Isomerism.

The phenomenon of reversible isomeric change had been studied, and its essential characteristics had been fully elucidated, twenty-two years before by Butlerow (17) in 1877. He had shown that two isomeric forms of the unsaturated hydrocarbon, *iso*dibutylene, C_8H_{16}, could be brought into equilibrium by the reversible addition of sulphuric acid, since a molecule of sulphuric acid could be removed from the acid sulphate in two different ways. Simultaneously, two *iso*dibutyl alcohols of the formula $C_8H_{18}O$, in the form of their acid sulphates, were brought into equilibrium by the reversible elimination of sulphuric acid, since the resulting olefine could add on sulphuric acid in two different ways:



Butlerow also recognised that, although sulphuric acid was required to bring the isomeric olefines and alcohols into equilibrium, the introduction of a catalyst might not be required in other cases. In particular he suggested that prussic acid might be regarded as an equilibrium-mixture of the two acids, HCN and HNC, from which the cyanides and *iso*cyanides $CH_3.CN$ and $CH_3.NC$ are derived:

$$CH_3.CN \longleftarrow HCN \rightleftharpoons HNC \longrightarrow CH_3.NC$$

Methyl cyanide. Prussic acid. Methyl *iso*cyanide.

Butlerow's paper did not receive the attention that it deserved, perhaps because it was published under the too modest title 'On Isodibutylene.' Much more interest was aroused by the publication, eight years later, by

Laar (18), of a speculative paper ' On the possibility of several structural formulæ for the same chemical compound.' Laar assumed that the dual reactivity of certain substances, of which ethyl acetoacetate is now the most familiar example, might be due to the incessant wandering of a hydrogen atom between two alternative positions in the molecule. In order to make his theory more precise, he compared these internal migrations with the vibrations which give rise to radiation in incandescent gases. To this phenomenon he gave the name of *tautomerism*, and in order to emphasise the contrast with Butlerow's phenomenon of reversible isomeric change, he stated categorically (19) that the substances represented by the two alternative structural formulæ were ' not isomeric but identical.'

Since two isomeric forms of π-bromonitrocamphor had been isolated in the crystalline state and their slow progress towards equilibrium in solution had been followed by observations of mutarotation, it would have been absurd to describe them as identical, or, in terms of Laar's definition, as tautomeric. These well-defined compounds, however, provided an excellent illustration of Butlerow's phenomenon of ' equilibrium between isomers.' I therefore ventured to describe this phenomenon in very obvious terms as *dynamic isomerism* (20), in contrast to the more usual condition of static isomerism, in which each isomer preserves its individuality and is not in process of conversion into any other member of the series. A full report on ' Dynamic Isomerism ' was presented to Section B of the British Association at Cambridge in 1904, and reports of a Committee on Dynamic Isomerism are included in the Transactions of Section B from 1905 to 1916. A series of twenty-eight papers on the same subject has also been published in the *Journal of the Chemical Society*.

Arrest of Mutarotation.

Further fortuitous observations showed that the mutarotation of nitrocamphor is not an independent intramolecular process, but depends on extramolecular circumstances, since under favourable conditions it may be arrested more or less completely over a period of several days (21). This discovery (which was made more than twenty years before Kurt Meyer's experiments (22) on the aseptic distillation of ethyl acetoacetate in alkali-free vessels of silica glass) was also the result of a fortunate accident. The mutarotation of a solution of nitrocamphor in chloroform had been followed to completion during a period of about eight days, but had been accompanied by some loss of solvent (and possible concentration of the solution) by evaporation. The remainder of the solution had been left in the small graduated flask in which it had been prepared, and there was no reason to suspect that it would behave in any respect differently from the sample in the polarimeter tube. It was therefore a great surprise when, at the end of seventeen days, on attempting to confirm the *final* reading, it was found that the residue in the flask gave a rotation almost identical with the *initial* reading recorded more than a fortnight before. The transfer of the solution to the polarimeter tube, however, sufficed to initiate the mutarotation, which then proceeded with the same velocity as before.

Nearly ten years later a further series of experiments was being made on the catalysis of mutarotation by acids and bases (23). It was then observed that solutions of nitrocamphor in chloroform, to which trichloracetic acid had been added, developed an intolerable and pungent odour. This observation showed that the peculiar inertness of chloroform was due to its oxidation to carbonyl chloride or phosgene, and to the consequent elimination of traces of nitrogenous bases, in the form of inert carbamides (24). The same series of experiments had already shown that some of these bases have an amazing catalytic activity. Thus an acceleration of mutarotation was detected as a result of adding piperidine to benzene in the proportion of 1 part of the base in 10 million parts of the solvent! This acceleration was also one of the earliest examples of a phenomenon which has since become very familiar, namely, a catalysis by bases, which could not be attributed to the presence of hydroxyl ions, and was therefore outside the scope of the conventional theories of catalysis by acids and bases, as developed and used by Ostwald and his colleagues.

An immediate sequel to this discovery was the arrest *in silica vessels* of the mutarotation of solutions of nitrocamphor in *benzene* and in *ether*, to which traces of an anticatalyst had been added (24). Subsequent experiments showed that mutarotation could also be arrested in solutions of tetramethylglucose in chloroform, benzene, ethyl acetate, and pyridine (25); and Owen (26) developed to a fine art the process of arresting, almost at will and with very few failures, the mutarotation of solutions of tetra-acetylglucose in dry ethyl acetate.

The climax of this work was reached when Faulkner (27) found that the mutarotation of tetramethylglucose could be arrested both in cresol and in pyridine, but proceeded too rapidly for convenient observation in mixtures of these two solvents. Since these mixtures gave velocities of mutarotation which were much greater even than in water, it was clear that the essential factor in promoting mutarotation was not an *oxygenated solvent* (28), nor an *ionising solvent* (29) (as had been suspected at earlier periods), nor even the *ionisation of the sugar* by an acid or basic catalyst (as most other workers had assumed), but that an *amphoteric solvent* (27) must be provided to serve as a complete catalyst for the process.

Prototropy.

The migration of a hydrogen atom, in compounds such as nitrocamphor and the sugars, was thus shown to depend on the addition and removal of a proton at two opposite poles of the organic molecule. Since no satisfactory name had been adopted for this important group of isomeric changes, I proposed in 1923 to describe them by the term *prototropy* (30). The migration of a proton was, however, regarded as only a special example of the more general phenomenon of *ionotropy* (31), in which a radical migrates from one part of a molecule to another either as an anion or as a kation.

The addition and removal of the ion from the two poles of the organic molecule may be either simultaneous or consecutive, but in either case

it leaves behind a positive or negative charge. In order that this type of isomeric change may proceed, it is essential that these opposite charges should be neutralised. The electronic theory of valency allows us to recognise that this is done by the rearrangement of bonds (or 'desmotropy') (32) which accompanies prototropic change, since a valency electron is thereby transferred *through the interior of the molecule*, to neutralise the charge of the proton, which is transferred *through the amphoteric solvent*.

The migration of a hydrogen atom, to which the most fertile types of mutarotation are due, was thus linked up to an extended definition of acids and bases, which I set out in 1923 (33), at a time when it must have been in the minds of many other workers, and which was described more fully by Brönsted a few months later (34). Thus, if we define an acid and a base as a proton donor and acceptor respectively,

$$B + HA \rightleftharpoons \overset{+}{B}H + \overset{-}{A} \text{ (where B is the base and HA the acid),}$$

the migration of a proton in a prototropic compound under the combined action of a base B and an acid HA can be expressed by the equation

$$B + HS + HA \rightleftharpoons \overset{+}{B}H + SH + \overset{-}{A},$$

used by Brönsted and Guggenheim (35), where HS and SH represent the two isomeric forms of the substrate. In an amphoteric medium such as water, catalysis by bases and acids can be represented by equations in which water plays the part either of an acid or of a base, thus :

Catalysis by a base: $B + HS + HOH \rightleftharpoons \overset{+}{B}H + SH + \overset{-}{O}H$

Catalysis by an acid: $H_2O + HS + HA \rightleftharpoons H_3\overset{+}{O} + SH + \overset{-}{A}.$

Finally, the possibility of autocatalysis must be recognised. Thus, since nitrocamphor is a strong acid, it may itself act as the acidic component of the catalyst ; mutarotation may than proceed by adding only a base, which in these conditions may become a complete catalyst for the mutarotation.

The process of isomeric change, as set out above, can be regarded as an electrolysis of the organic molecule between positive and negative poles, provided by the acid and basic components of the amphoteric solvent. This mechanism has therefore been described (36) as an 'electrolytic theory of catalysis by acids and bases.' Similar conditions, however, prevail in all conjugated systems, and these can now be formulated in general terms, as systems in which opposite charges at the ends of the system can be neutralised by a migration of valency electrons through the system (37).

Rotatory Dispersion.

At the time when the earlier measurements of mutarotation were made, it was customary to measure the optical rotations of organic compounds only for the yellow sodium line. Work on rotatory dispersion had indeed been suspended almost completely since the death of Biot in 1862, and

the discovery of the Bunsen burner in 1866. It was, however, certain that little progress could be made in elucidating the origin of optical rotatory power, or in predicting its magnitude, until the values of the rotatory power were known over a wide spectral range, instead of for a single casually determined point on the curve of rotatory dispersion. This opinion has received abundant confirmation from the subsequent demonstration that the substances which had provided the favourite materials for studies of optical rotatory power were those whose rotatory dispersion was most anomalous, since these substances are in fact (and perhaps inevitably) most sensitive to changes of solvent, concentration, or temperature.

The ignorance then prevailing in reference to this important aspect of the subject is shown by the fact that, when Drude wished to test his equation for optical rotatory dispersion, he was only able to make use of data for quartz (38), since the rotatory dispersion of no one of the hundreds of optically active compounds prepared and studied by organic chemists was known with sufficient accuracy to be used for this purpose ; and his equation for magnetic rotatory dispersion was tested on data, for five wave-lengths only, for carbon disulphide and for creosote ! (39)

Experiments carried out in order to supply the data required to determine the form of the curves of rotatory dispersion in organic compounds soon led to definite conclusions. Thus in 1913 I was able to show, with T. W. Dickson (40), that the optical rotations of ten simple alcohols, and the magnetic rotations of thirty-four simple organic compounds for eight wave-lengths in the visible spectrum could be expressed by *one* term of Drude's equation :

$$\alpha = k/(\lambda^2 - \lambda_0^2).$$

In the following year we found (41) that *two terms of opposite sign*:

$$\alpha = \frac{k_1}{\lambda^2 - \lambda_1^2} - \frac{k_2}{\lambda^2 - \lambda_2^2}$$

could be used in the same way to express the anomalous rotatory dispersion of ethyl tartrate. This result confirmed the conclusion reached at a much earlier period by Biot (42) and by Arndtsen (43), that anomalous rotatory dispersion has its origin in the superposition of two partial rotations of opposite sign and of unequal dispersion. These partial rotations may be due to very diverse causes, ranging from the presence of two optically active absorption bands in the same molecule, to the case in which two liquids of opposite rotatory power and unequal dispersions are arranged in series in separate polarimeter tubes. This diversity has resulted in a certain amount of controversy as to the *origin* of the partial rotations which give rise to anomalous rotatory dispersion (44), but the essential facts represented by Drude's equation are established beyond dispute.

Validity of Drude's Equation.

Since Drude's equation is only applicable to transparent media, the limits of validity of the equation coincide with the conditions under which

a maximum of experimental accuracy can be obtained, namely, by using long columns of concentrated solutions. Under these conditions the validity of the equation has been vindicated up to the limits of experimental accuracy for a single term in octyl alcohol (45) and for two terms in ethyl tartrate, drastically purified by crystallising to constant melting-point (46).

An extreme limit has been reached in the case of quartz, where measurements to six significant figures have been made for twenty-four wave-lengths in the visible spectrum, on a column nearly half a metre in length. This column gave a rotation of 12,678·96° for the green mercury line Hg 5461 ; and when the ten sections of the column were dismantled and re-erected, the original reading was reproduced with an error of only 0·03°, or less than three parts in a million (47).

In the infra-red region, the rotation per millimetre falls from 25·539° per mm. at 5460·742 Å.U. to 2° at 18,000 Å.U., 1° at 25,000 Å.U., and 0·74° at 28,000 Å.U. Observations are then interrupted by an absorption band ; but beyond this there is a narrow window through which observations can be made before the medium again becomes opaque. Snow's measurements (48) have shown that the rotations in this narrow region of transparency (about 0·52° per mm. at 32,000 Å.U.) fall on the same curve, and can be expressed by the same formula, as those in the infra-red, visible and ultra-violet regions. The infra-red absorption band is therefore, as Drude supposed, without influence on the course of the curve of rotatory dispersion.

In the ultra-violet the rotations increase very rapidly. Thus for a copper line at 2263 Å.U. the observed rotation of the half-metre column rose to 101,332°, or 202·328° per mm. (47).

Throughout the whole range from 32,100 to 2263 Å.U. the rotatory dispersion of quartz for about 1000 wave-lengths can be expressed within very narrow limits by two terms of Drude's equation, of opposite sign, together with a small constant (47):

$$\alpha = \frac{9\cdot5639}{\lambda^2 - 0\cdot0127493} - \frac{2\cdot3113}{\lambda^2 - 0\cdot000974} - 0\cdot1915$$

This equation does not express with equal accuracy the observations made by Duclaux (49) at still shorter wave-lengths with a much shorter column of quartz, but it predicts with considerable precision the existence of two absorption bands, with characteristic frequencies far out in the Schumann region at 1130 and 310 Å.U. I am still waiting, however, for a physicist to carry out the experiments which are needed to disclose the presence of these two bands, the existence of which has already been predicted for nearly a quarter of a century.

Normal and Anomalous Rotatory Dispersion.

Experiments such as these have demonstrated, beyond the possibility of controversy, the ability of Drude's equation to express the rotatory dispersion of transparent media up to the extreme limits of accuracy

which are now attainable (52). Thus *normal* rotatory dispersion (defined by the fact that α, $d\alpha/d\lambda$ and $d^2\alpha/d\lambda^2$ are of constant sign throughout the region of transparency (50)) can often be expressed by a single term of the equation, with only two constants ; but this is by no means universally true, since the rotatory dispersion of quartz, which requires a five-constant equation, is nevertheless rigidly normal throughout the whole region of transparency. On the other hand, *anomalous* rotatory dispersions can only be expressed by using two terms of opposite sign. These two terms, however, are adequate to account for the presence in curves of anomalous rotatory dispersion of (i) a *reversal of sign*, where $\alpha = 0$, (ii) a *maximum*, where $d\alpha/d\lambda = 0$, and (iii) an *inflexion*, where $d^2\alpha/d\lambda^2 = 0$ (50).

Those normal rotations which cannot be expressed by a single term of Drude's equation can usually be represented by equations with two terms, either of similar or of opposite signs. When the two terms are of opposite signs, the equation becomes identical in form with that which is used to represent anomalous rotatory dispersion. The distinction between normal and anomalous dispersion is indeed often almost a matter of accident. Thus a wide range of dispersion-curves can be plotted for the tartaric esters in different solvents, and at different concentrations and temperatures (51). These curves all belong to one family, and can be expressed by the same equation, with small variations in the four arbitrary constants ; but some of them cross the zero axis and are therefore anomalous, whilst others just fail to do so and are therefore normal (52).

Simple and Complex Rotatory Dispersion.

An alternative method of classification is to describe as *simple* those rotatory dispersions which can be expressed by one term of Drude's equation, and as *complex* those which cannot be so expressed (53).

This classification lends itself very easily to practical use, since, for the purpose of complete verification, measurements need only be extended to a wave-length in the ultra-violet at which absorption first begins to be troublesome, in view of the fact that Drude's equation is only valid in the region of complete transparency. On the other hand, the distinction between normal and anomalous rotatory dispersion depends on knowing whether the curve does or does not cross the zero axis in the infra-red ; and this cannot yet be determined with certainty with the apparatus now commonly used in polarimetry.

In general, simple rotatory dispersions are only observed when the characteristic frequencies of all the partial rotations lie close together in the Schumann region, giving a dispersion-ratio $\alpha_{4358}/\alpha_{5461} = 1{\cdot}6$ approximately. Thus, in the sugar series, the partial rotations associated with the different asymmetric carbon atoms sometimes give rise to a simple dispersion, as in cane-sugar (54) ; but they do not necessarily do so (55), since even in a sugar the characteristic frequencies of the radicals may cover a wide range in the Schumann region, and the foot of the absorption bands often extends into the ordinary ultra-violet.

Additional partial rotations of lower frequency give rise to dispersion-

ratios which are either higher or lower than this value, according as they are of the same or of opposite sign as the partial rotations associated with absorption bands in the Schumann region. In the remarkable case of tetra-acetyl-μ-arabinose, $H[CHOAc]_4.CHO$, however, the partial rotations associated with the three asymmetric carbon atoms cancel out (56). The whole of the rotatory power is therefore due to the partial rotation associated with the carbonyl group. This gives rise to a simple rotatory dispersion in the region of transparency. In the region of absorption it gives a symmetrical loop, with equal and opposite maxima $[\alpha] = \pm 1200^\circ$ on either side of a zero rotation at 2909 Å.U. Camphorquinone is a less precise example of the same phenomenon, since its rotation in a narrow region of transparency in the red, yellow, and green is dominated by an absorption band in the blue. The influence of the Schumann terms is therefore so small that the rotatory dispersion can be expressed by a single term of Drude's equation (54).

Simple rotatory dispersion then does not imply the existence of only a single partial rotation, but merely indicates that the partial rotations of the molecule can in practice be covered by one term of Drude's equation. It provides, however, the most practical way of classifying rotations, since no real physical meaning can be assigned to a rotation which is not 'simple,' until the various partial rotations, which make the rotatory dispersion 'complex,' have been unravelled. For this purpose, however, a precise algebraic analysis must be made of the observed rotations for a large number of wave-lengths; and no sanction can be given to the use of graphical methods, except for the rough preliminary tests for which alone they are suitable (57).

Rotatory Dispersion in Absorbing Media.

A formula for rotatory dispersion in a region of absorption was developed by Natanson (58) in 1909, by reintroducing a 'damping factor' which Drude had discarded in his final simplified equation for rotatory dispersion in transparent media (59). No basic change has been made in the fundamental relation thus developed between absorption and rotation; but Kuhn and Braun (60) found that, since the form of the absorption bands cannot be expressed by means of a damping factor, the form of the corresponding curves of rotatory dispersion is also incorrect. They therefore introduced a new series of equations on the supposition that the form of the absorption band can be expressed by an exponential equation representing a Maxwellian probability-distribution of *frequencies*. Their equations are an improvement on those of Ketteler, Helmholtz and Natanson; but absorption curves of the form postulated by them are so uncommon that, in the course of a long experience of absorption spectroscopy, I have not yet discovered a single example of this type. On the other hand, several absorption curves have been studied which are rigidly symmetrical on a scale of *wave-lengths*, and many more are known which shade off more slowly at higher frequencies. Hudson (61) has therefore developed a modified series of equations for substances which give rise to these symmetrical absorption curves. His equations express his own very exact measurements with far greater precision than

the equations of Kuhn and Braun. Thus, in the fascinating case of tetra-acetyl-μ-arabinose, where the positive and negative maxima are equal in magnitude, the equation of Kuhn and Braun gives a difference of 200° between the observed and calculated values ; but this was reduced to only 30° by using Hudson's own equation (56).

This sugar-derivative provides ideal material for an experimental study of the form of the curves of rotatory dispersion in the region of absorption, since the partial rotation associated with the carbonyl-radical has been isolated automatically by a fortunate process of cancellation of the partial rotations of the asymmetric carbon atoms. A similar cancellation has been observed more recently by Baldwin in a specimen of penta-acetyl-μ-fructose, also supplied by Dr. Wolfrom. Although the simple aldehydic radical —CO.H has now been replaced by the radical $—CO.CH_2.O.CO.CH_3$, this compound again gives rise to equal maxima on either side of the axis ; but, since the configuration of the three asymmetric carbon atoms is reversed, these maxima are of opposite sign to those observed in the arabinose-derivative. Moreover, the absorption curves have not the same ideal symmetry, and the mathematical analysis of the dispersion curves has therefore not yet been completed.

The Origin of Optical Rotatory Power.

Attempts to simplify the structure of an optically active molecule for the purpose of numerical calculations have been made by Drude (59), who used a model consisting of a vibrator moving in a spiral orbit, whilst Kuhn (62) has used a model consisting of two dissymmetrically coupled electrons. Each of these models includes a *length*, namely, the pitch of the spiral or the distance between the coupled electrons, and it is perhaps not surprising that they have led to equations which differ only in the meaning assigned to the arbitrary constants ; but in certain cases at least the length deduced from Kuhn's model appeared to bear no relation to the linear dimensions of the molecule. Fortunately the formulæ which express the rotatory dispersion of a medium do not depend on the nature of the model used to deduce them, although new integrals are required to correspond with each new distribution of densities in the optically active absorption band. This distribution depends on the intensities of the sub-levels associated with a given electronic jump, and cannot yet be predicted. In these circumstances it is remarkable that the absorption curve should be symmetrical even in the few cases studied by Hudson ; but this result may perhaps be interpreted as the effect of some limiting condition, which prevents the appearance even of curves which are symmetrical on a scale of frequencies instead of wave-lengths.

The real theory of optical rotatory power may be found by the mathematician, but is concealed from the chemist, in the papers of Born (63), who recognised that *four* coupled electrons are required to produce optical rotatory power. Further advances appear to depend on reverting to this basis, in place of Drude's single spirally controlled vibrator, or Kuhn's two dissymmetrically coupled electrons, since neither of these conceptions can be realised except in a complicated field of force,

depending presumably on the distribution of nuclei as well as on the distribution of electron-densities as studied by W. L. Bragg and others. It is, indeed, an interesting exercise to construct a model of the molecule of camphor and then to inquire to which other electrons the shared valency-electrons of the carbonyl group must be coupled, in order to develop the magnificent loop which appears in the curve of rotatory dispersion in the region of absorption. The question answers itself by mere inspection of the model, since it is clear that *all* the electrons are involved, and not merely one, two or four of them. Thus, even when the carbonyl group has been linked to two dissimilar radicals, either in an open-chain ketone or in a cyclic ketone, no rotatory power at all is developed. The whole of the rotatory power of camphor therefore depends on the contrast between the two radicals $—CH_2.CH_2—$ and $—C(CH_3)_2—$ which lie on either side of the plane which contains the $—CH_2.CO—$ radical. These two chains are separated from the carbonyl-radical by an unbridged gap, since the route which leads to them through the bonds is long and tortuous. It therefore seems clear that we are dealing with an intramolecular field of force, acting across two empty spaces, which destroys the symmetry of the environment and thus brings out the latent possibility of dissymmetry in the highly-polarisable carbonyl group.

The picture thus exhibited directs attention to the carbonyl group, rather than to the asymmetric carbon atoms, which in the acetate of μ-arabinose make no direct contribution of any importance to the rotatory power of the molecule. In this respect it is indeed essentially identical with the conception of *induced asymmetry* (or better *induced dissymmetry*) put forward by Lowry and Walker in 1924 (64), according to which the carbonyl group itself becomes dissymmetric under the influence of the dissymmetric internal field of force of the molecule. It therefore contributes directly to the optical activity of the molecule, whereas less polarisable groups, such as $>CH_2$ or $>CMe_2$, contribute relatively little to the total rotation, even when they are exposed to a similar dissymmetric field.

I have had the privilege of talking over this problem with Prof. Born. He insists that the rotatory power thus induced in the carbonyl group cannot be expressed in terms of single potential-gradients along and across the plane of the $—CH_2.CO—$ group, but must be a function of the frequencies of the electrons with which the carbonyl group is coupled, since this coupling affects the frequencies of both components. It is, however, possible that in a monoketone, such as camphor, the characteristic frequencies of the hydrocarbon radicals on either side of the median plane may be summed up in a weighed mean, depending but little on the structure or configuration of the carbon skeleton. In that case regularities and simplifications may perhaps be encountered, in studying different cyclic ketones, which could not have been foreseen from the complexities of pure theory.

Prediction of the Sign and Magnitude of Optical Rotatory Power.

The electronic theories discussed above have not hitherto led to any prediction of the magnitude of the optical rotatory power of a dissym-

metric molecule, although Hermann has calculated the rotatory power of crystals of sodium chlorate and Hylleraas that of β-quartz from formulæ developed by Born. For the purpose of predicting the magnitude of the rotatory power of a molecule it is convenient to deal, not with single electrons or pairs of electrons, or even groups of four, but with the complete octet which constitutes the valency-shell of the atom. From this point of view, the four different radicals which are required to give rise to an asymmetric carbon atom may be considered as ellipsoids, with three principal axes of polarisation, arranged at a definite distance from the central carbon atom and with a definite orientation relatively to one another; but this system is too complex for easy computation and some simplification is needed before numerical data can be deduced.

This simplification was attempted nearly ten years ago by de Mallemann (65), who assumed that, for the purpose of computation, single atoms might be treated as isotropic spheres. A further simplification was made by assuming that the three halogens in CHClBrI could be placed on the rectangular axes of x, y and z at distances depending on their atomic radii. On this basis he calculated (66) the rotatory power of the molecule in terms of the radii and refractivities of the radicals, and obtained a value, $[\alpha]_D = \pm 3 \cdot 2^\circ$, of the expected order of magnitude for a compound of this type; but, since the compound has not yet been prepared, no direct comparison of observed and calculated rotations was possible. During the present year, however, S. F. Boys (67) has been able to make this comparison by extending the postulate of isotropic spheres from single atoms to radicals. Langmuir's theory of isosterism can be cited as justification for extending this postulate from the halogens to the isosteric radicals, OH, NH_2, CH_3; but it is certainly invalid when extended to radicals such as C_2H_5 and CH_2OH, which cannot be either spherical or isotropic. Nevertheless Boys has been able to deduce, for four of the simplest alcohols and amines, rotations which are of very similar magnitude to those observed experimentally. This coincidence is limited to dissymmetric molecules of the simplest possible type, containing only one asymmetric carbon atom and no unsaturated or chromophoric group; but it is sufficient to show that Pasteur's model of an irregular tetrahedron can be used to predict the existence and the approximate magnitude of such a molecule in terms of the linear dimensions and the refractive indices of the radicals.

Detailed calculations by Mr. H. F. Willis have shown that the simple rotatory dispersion of *sec*-butyl alcohol, $\alpha_{4358}/\alpha_{5461} = 1 \cdot 661$, can be deduced exactly from the factor $R_A R_B R_C R_D/\lambda^2$ of Boys' formula, or less exactly if the factor $(\mu^2+2)(\mu^2+5)$ is included. On the other hand, the dispersion-ratio of *act*-amyl alcohol, $\alpha_{4358}/\alpha_{5461} = 1 \cdot 700$, is higher than the maximum value which can be deduced from the formula. Moreover, the anomalous rotatory dispersion of aldehydes and ketones in the region of absorption cannot be represented even qualitatively by means of a formula of this kind, since the refractivity of the carbonyl-radical never approaches the zero axis, and cannot therefore give rise to a reversal of sign in the region of absorption; but a zero value for the

partial rotation of the carbonyl-radical might perhaps become possible by assuming with Lowry and Walker that an additional centre of dissymmetry is developed *within the chromophoric group* in optically active aldehydes and ketones.

From the above considerations it appears that the molecular theory of optical rotatory power, as de Mallemann has called it, is not capable in its present form of expressing the rotatory power of any but the simplest molecules ; and the crudeness of some of the assumptions on which it is based, and the importance of the secondary effects which it ignores, forbid any expectation of extensive developments in the near future. Nevertheless the theory has proved to be of real value in demonstrating the simplicity of the conditions which suffice to give rise to optical rotatory power, since this effect can be produced by four isotropic spheres which are near enough to pass on to one another the alternating polarisation produced by an incident beam of light, without requiring any more complex form of coupling ; and chemists will always be grateful for a theory of optical rotatory power which makes it possible to identify the actual configurations of the dextro- and lævorotatory forms of the simplest organic molecules, in parallel with a similar claim which has recently been made by Kuhn in the more complex case of the spiro-compounds (68). On the other hand, no theory of optical rotatory power which is limited to the region of transparency can be regarded as satisfactory, and further progress must depend on an intensive study of rotatory dispersion in the region of absorption. For this purpose the optically active aldehydes and ketones provide ideal material, since the position and intensity of the optically active absorption bands are both well adapted for precise experimental work, and two cases are already known in which the partial rotation of the chromophoric radical has been automatically isolated. It therefore only remains to determine, perhaps by the methods of wave-mechanics, the conditions under which the electronic cloud of the carbonyl-radical becomes optically active, and the factors which determine the magnitude of its partial rotation, in order to provide a complete solution for this special case, and thus to pave the way for a general solution of the whole problem.

References.

1. Walker, ' Arrhenius Memorial Lecture,' *J. Chem. Soc.*, 1928, 1400.
2. Ostwald, ' Faraday Lecture,' *J.*, 1904, **85**, 508.
3. Sommerfeld, *Atombau und Spektrallinien.*
4. Oliphant, *Nature*, 1934, **133**, 377.
5. Lowry, *J.*, 1898, **73**, 569.
6. —— *J.*, 1898, **73**, 986.
7. —— *J.*, 1899, **75**, 211.
8. Dubrunfaut, *C.R.*, 1846, **23**, 38.
9. Wheeler and Tollens, *Ann.*, 1889, **254**, 310.
10. Lowry, *J.*, 1899, **75**, 213.
11. —— *J.*, 1898, **73**, 991.
12. Lapworth and Kipping, *J.*, 1896, **69**, 304.

13. Lowry, *J.*, 1899, **75,** 223.
14. E. Fischer, *Ber.*, 1890, **23,** 2626.
15. Schmöger, *Ber.*, 1880, **13,** 1917 ; 1881, **14,** 2121 ; 1892, **25,** 1455. Tanret, *C.R.*, 1895, **120,** 1060.
16. Trey, *Z. physikal. Chem.*, 1895, **18,** 193. Lippmann, *Ber.*, 1896, **29,** 203. Tanret, *Bull. Soc. Chim.*, 1896, [iii], **15,** 195.
17. Butlerow, *Ann.*, 1877, **189,** 44.
18. Laar, *Ber.*, 1885, **18,** 648.
19. —— *Ber.*, 1886, **19,** 730.
20. Lowry, *J.*, 1899, **75,** 211.
21. —— *ibid.*, p. 220.
22. Kurt Meyer, *Ber.*, 1920, **53,** 1410 ; 1921, **54,** 579.
23. Lowry and Magson, *J.*, 1908, **83,** 107.
24. —— *ibid.*, p. 119.
25. Lowry and Richards, *J.*, 1925, **127,** 1385.
26. Lowry and Owen, *Proc. R.S.*, 1928, A, **119,** 505.
27. Lowry and Faulkner, *J.*, 1925, **127,** 2883.
28. Lowry, *J.*, 1899, **75,** 219.
29. *See* Lowry and Magson, *J.*, 1908, **83,** 129.
30. Lowry, *J.*, 1923, **123,** 828.
31. Lowry, *Second Solvay Conference*, 1926, p. 158.
32. Jacobsen, *Ber.*, 1887, **20,** 1732 ; 1888, **21,** 2628.
33. Lowry, *Chem. and Ind.*, Jan. 19, 1923, **1,** 43 ; compare *Trans. Faraday Soc.*, 1930, **26,** 45.
34. Brönsted, *Rec. Trav. Chim.*, 1923, **42,** 718 ; compare *Trans. Faraday Soc.*, 1929, **25,** 59.
35. Brönsted and Guggenheim, *J. Amer. Chem. Soc.*, 1927, **49,** 2554.
36. Lowry, 'L'Activation et la Structure des Molécules,' *Réunion Internationale de Chimie Physique*, 1928, p. 219.
37. Lowry, *Nature*, 1925, **115,** 376.
38. Drude, *Theory of Optics*, English Trans., London, 1907, p. 414.
39. —— *ibid.*, p. 439.
40. Lowry and Dickson, *J.*, 1913, **103,** 1067.
41. —— *Trans. Faraday Soc.*, 1914, **10,** 99.
42. Biot, *C.R.*, 1836, **2,** 543.
43. Arndtsen, *Ann. Chim. Phys.*, 1858, **54,** 421.
44. Hunter, *J.*, 1924, **125,** 1198.
45. Lowry and Richards, *J.*, 1924, **125,** 1593.
46. Lowry and Cutter, *J.*, 1922, **121,** 532.
47. Lowry and Coode-Adams, *Phil. Trans.*, 1927, A, **226,** 391 ; compare Lowry, *ibid.*, 1912, A, **212,** 261.
48. Lowry and Snow, *Proc. R.S.*, 1930, A, **127,** 271.
49. Duclaux and Jeantet, *J. Physique*, 1926, **7,** 200.
50. Lowry, *J.*, 1915, **107,** 1195.
51. Lowry and Dickson, *J.*, 1915, **107,** 1173.
52. Lowry, *J.*, 1929, 2858.
53. Lowry and Dickson, *Trans. Faraday Soc.*, 1914, **10,** 102.
54. Lowry and Richards, *J.*, 1924, **125,** 2511.
55. Harris, Hirst and Wood, *J.*, 1932, 2108.
56. Hudson, Wolfrom and Lowry, *J.*, 1933, 1179.
57. Lowry and Abram, *J.*, 1919, **115,** 303 ; compare Hunter, ref. 44.
58. Natanson, *Bull. Akad. Sci., Krakow*, 1908, No. 8, 764.
59. Drude, *Optik*, Leipzig, 1900.
60. Kuhn and Braun, *Z. physikal. Chem.*, 1930, B. **8,** 281.
61. Lowry and Hudson, *Phil. Trans.*, 1933, A, **232,** 117.

62. W. Kuhn, *Trans. Faraday Soc.*, 1930, **26,** 293.
63. Born, *Phys. Zeit.*, 1915, **16,** 251 ; *Ann. Physik*, 1918, [iv], **55,** 177.
64. Lowry and Walker, *Nature*, 1924, **113,** 565. Lowry, *Nature*, 1933, **131,** 565.
65. de Mallemann, *Rev. Gen. Sci.*, 1927, **38,** 453 ; *Trans. Faraday Soc.*, 1930, **26,** 281.
66. —— *C.R.*, 1925, **181,** 298.
67. S. F. Boys, *Proc. Roy. Soc.*, 1934, A, **144,** 655.
68. W. Kuhn, *Ber.*, 1933, **66,** 166 ; *Z. physikal. Chem.*, 1934, B. **24,** 335.

SECTION C.—GEOLOGY.

PLANT LIFE AND THE PHILOSOPHY OF GEOLOGY

ADDRESS BY

PROF. W. T. GORDON, M.A., D.Sc.

PRESIDENT OF THE SECTION.

At a recent celebration [1] the President of the Royal Society, Sir Frederick Gowland Hopkins, said ' It has been remarked, and not without a measure of truth, that the scientific investigator is more readily forgotten even by his own world than is the author or the artist. A literary work or a picture is complete in itself. It is an accomplishment involving finality and it remains intact through the years. . . . The investigator of Nature, on the other hand, adds his quota to a growing structure, to the great edifice of science as a whole, and as knowledge grows and widens and others build upon his work as a foundation it may become, as it were, submerged.' What is true of the individual worker may be equally true of his subject, and the influence of research, when viewed out of its original setting, may be completely lost. To an extent this has happened in connexion with the study of fossil plants in their relation to geological science, and the request of the Council that the Sections, at this year's meeting, might explore the possibility of illustrating how far their particular science had added to the sum total of human advancement has afforded a chance to consider this matter. Geology is the science that investigates the past history of the earth, and, as a consequence, involves considerations of the past life of the earth, both animal and plant. Discussions of past life will, of necessity, involve investigations of life conditions, and these will react on ideas of inorganic nature. So far as human beings are concerned, we have no difficulty in appreciating the economic side of geology ; but there is another side—the advancement of thought—that is not quite so obvious to ' the man in the street.'

Our study this morning is largely historical, and the views of the ancients will form a suitable beginning. We cannot accredit any real scientific knowledge of geology to them, but their utilisation of stone and metals shows that they were not unacquainted with phenomena now considered by the geologist as among the data of his science. Even in pre-historic times observation of, and inference from, natural phenomena cannot be denied. In a late neolithic hearth at Gullane, East Lothian, I have collected a piece of petrified wood—*Pitys primæva*—of Carboniferous age

[1] Unveiling of a plaque to William Hyde Wollaston on 14 Buckingham Street, W.C. 1, on July 4, 1934.

which certainly had deceived its collector. It is so well preserved, and so resembles a billet of wood, that even to-day a casual observer might have taken it for a piece of weathered drift-wood. While this must be one of the earliest known specimens actually collected and used by man, we can hardly say that its study led to any direct advance. Nor did the well-known specimen of *Cycadeoidea etrusca*, Capellini, found in a tomb twenty miles west of Bologna, signify anything more than that it had struck the curiosity of some ancient Etruscan. Neither the utilitarian outlook of the prehistoric Scot nor the curiosity of the Etruscan had any recorded result in further research. Other known uses of fossil plants by the ancients, such as the employment of logs of fossil wood by the Egyptians in making roads over the desert, and in fabricating ornaments, or the tools made out of the Rhynie chert, are likewise without any real significance from a geological point of view. They are all interesting, but have not led to further developments.

Palæontological Ideas in Classical Times.

Among the Greek and Roman philosophers there is no doubt that many were acquainted with fossils, and *inter alia* with fossil plants, but again the geological import of these objects was hardly considered. They were accepted as of organic origin, and their presence in rocks was attributed variously to former inundations of the land or a *vis plastica*. That they were remnants of *former* worlds never seems to have struck them. Inundations of the land, or elevations of the land above the sea by earthquakes or volcanic action, they knew, and even successions of such changes,[2] but the great past history of the earth was still an unknown volume. Yet the naturalness of their deductions is often very striking. This applies perhaps with greatest force to the Geography of Strabo. The work was written for the instruction of administrators, and the sanity of the discussions and final conclusions, together with the fair-minded criticism of the authorities he quotes, is startling when one considers the ideas of many of his contemporaries, and of his predecessors. He is perhaps too generous to Homer, whom he seems to consider infallible, and the depository of all knowledge : but in this he only follows most of the Greek philosophers. The works of Aristotle, Theophrastus, Pliny, Herodotus and Seneca, that are extant, are all excellent in their way as illustrating here and there geological ideas prevalent before, and just after, the beginning of Christian times ; but Strabo excels them all.

Yet, with all their knowledge of the processes of nature, and of the plants and animals that inhabitated the earth, there does not appear a single hint of any former phase *different from the present*. In fact, although many geological processes and phenomena were known, there was no science of Geology. Yet the ancients have left us a legacy in their desire to find a natural explanation for the origin of everything. Curiosity to explore and explain nature seems to have been their watchword. For nearly 1,000 years from the beginning of the Christian era geological

[2] *Cf.* Ovid, *Metamorphoses*.

science made no progress. Doubtless many fossil plants and animals were discovered, but no record of them has been preserved to us.

Mediæval Ideas on Fossil Plants.

In the Middle Ages fossils, both plant and animal, were regarded, for the most part, as produced by inorganic agencies in the earth itself. Mr. W. N. Edwards, in his Guide to an Exhibition illustrating the early history of Palæontology, has made an interesting suggestion in regard to the reason for this. He considers that it may have arisen 'from a misunderstanding of the explanations of fossils' given by Avicenna. The quotation from Albertus Magnus (1193?–1280) in *De Mineralibus et rebus metallicis*, describing certain stones like animals, runs: 'And the cause of this is, according to Avicenna, that animals themselves in their entirety are sometimes changed into stones, and especially into salty stones. For he says that just as earth and water are the material of stones, so also are animals, which, when they pass into places in which the stone-forming essence is given forth to the elements, are seized by the properties of those qualities which are in such places. The elements in the bodies of the animals are changed into the ruling element, namely, the earthy mixed with the aqueous, and then the mineral virtue changes that into stone, and they retain their figures and parts both within and without as before.'

This might appear to be a crude description of petrification, after burial by natural causes in the earth, in suitable conditions, and not a statement that fossils were produced in the earth by some stone-forming essences. Yet the latter doctrine seems to have held the field.

Leonardo da Vinci (1452–1519) ridiculed the idea, as also did Fracastoro in 1517, but it persisted, and we find Agricola in his *De natura fossilium* (1548) adopting two views. He believed that some *materia pinguis* or *fatty matter* produced organic shapes by fermentation, but he also thought that plants and animals could be turned into stone by a *succus lapidescens*. Andrea Mattioli two years later (1548) described fossil fishes from Monte Bolca, and, from his own observations, believed that bones, etc., could be turned into stone by absorbing such a lapidifying juice; in modern phraseology by ground water containing mineral matter in solution. Yet not until the eighteenth century was the notion that these were merely *lusus naturae*, *lapides figurati*, or *lapides sui generis* finally killed by ridicule.

Now fossil animals, rather than plants, have figured in these discussions, and Brongniart has suggested that the explanation can be found in the fact that coal was not in such demand because of the abundance of timber in Europe, and consequently the principal repositories of fossil plants had not been explored: but that cannot excuse workers in this country at all events. The earliest coal lease, for the commercial exploitation of coal, was granted between 1210 and 1219 to the monks of Newbattle, Midlothian, by a Seyer de Quinci, as is recorded by Cochrane-Patrick,[3] while the Newcastle coalfield was working in 1239 under a charter of Henry III. It is inconceivable that the miners were unacquainted with

[3] Cochrane-Patrick, *Records of Mining in Scotland.*

specimens of the abundant flora that is associated with the coal in these and other areas ; so that the paucity of references to such fossils can only be attributed to apathy, or interests in quite other matters. There is no doubt that great quantities of coal were raised and employed, among other uses, for evaporating sea water to produce salt. Prior to 1567, for example, the 10th Earl of Sutherland had opened up the Brora coalfield ; and the coal was used by Lady Jean Gordon, not only for domestic purposes, but also for the salt pans working in the neighbourhood. That a goodly number of people were employed is shown by old records and implied by old laws against the ' colliers and salters ' (1606). Had there been only a small number of operatives employed, there would have been no need of Acts of Parliament to regulate their behaviour : so that everything goes to show an extraordinary lack of interest in the fossils they must have unearthed during their work. But, if fossil plants had not been mentioned very frequently in these ancient treatises, the time soon came when they were used with great effect.

The recognition, complete or partial, that these *lapides figurati* once were living organisms drove philosophers to attempt some explanation of their presence in rocks. In close proximity to the sea-board the presence of marine shells could be explained by elevation of the land, but their occurrence far inland, and at considerable heights and also deep down in mines, introduced difficulties. Men were not prepared to accept such wholesale drowning of the land as would be necessary. The first chapter of the Bible contains statements that the land was separated from the waters on the third day of Creation, and this was held to be the incontrovertible truth. But the Church also taught the occurrence of one great flood—Noah's flood—and this, for the time at any rate, presented a way out of the philosophical impasse. Scientific discovery and what was thought to be Divine revelation were once more in accord. Fossils were real organisms that had been overwhelmed at the flood. Now, as Suess [4] has shown, there is no event of pre-historic time so well authenticated as an inundation that terrified the Near Eastern world. Records of such an event are preserved in the traditions of many races round what is now Mesopotamia. Although the story of this occurrence had not been so well examined in these days as Suess has now done, yet it appeared in the sacred books of the Old Testament, and was thoroughly implanted in the philosophy of the Hebrews, and, consequently, in Christian philosophy.

Of course there were dissentients. Leonardo da Vinci (1452–1519), for one, could not accept the theory, for there were such obvious difficulties. We cannot estimate the effect of his dissent, for his writings were not published until long after his death ; but Fracastoro at any rate, who held similar beliefs, was a power in the land, and his views, set forth in 1517, had great influence. We have indeed to thank the Italian scientists of the fifteenth and sixteenth centuries for establishing the organic character of fossils, and for combating the notion of Noah's flood as an explanation of their presence in rocks. They were before their time, however, and their influence was destined to be eclipsed.

[4] *The Face of the Earth,* introductory chapters.

Interpretation of Fossil Plants in the Sixteenth and Seventeenth Centuries.

The greatest influence in the sixteenth century in geological philosophy was undoubtedly exercised by Georg Bauer, [Agricola] (1494–1555). His personality and his scientific attainments, both in the fields of theory and practice, place him far above all others. He was a man entirely devoid of bigotry, and took up the very common-sense view that some 'fossils' are inorganic, but some are remains of plants and animals. Gradually the organic nature of fossils was established as a principle of scientific philosophy. Palissy, whose collection contained 'more than a hundred pieces of wood turned into stone,' dared to assert in Paris in 1580 that fossil fishes had once lived, that they had not been deposited by a universal deluge, and that many of the fossils were different from living types. For his liberal views Palissy died miserably in the Bastille. Others, of the Italian scientists, put forward many theories, but, on the whole, defended the Noah's flood hypothesis.

It is perhaps unfortunate for my general thesis that the first treatise on pure palæobotany by Stelluti, in 1637, should have been one of the reversions to the inorganic origin of fossils. His work has many plates—excellent for their time—but his words are retrograde. 'The generation then of this wood as far as I have been able to see, and to observe carefully, does not proceed from seeds nor from roots of any plant, but merely from a species of earth which is rich in clay, which little by little must be changed into wood ; in this way nature works until all that remains is converted into wood ; it is in this way I believe with the aid of some subterranean fires, such as there are in some places, which go winding about underground and give off from time to time a fairly thick smoke, and at times flames, especially in rainy weather, and also with the additional assistance of sulphurated and mineral waters.'

Others write in what we would call a more progressive tone ; and Steno, the Dane, a professor in Padua, published in 1669 a work of the very first importance. He enunciated the law of superposition of strata ; the original horizontality of beds ; and that high dip of beds connoted earth movement. He distinguished between marine beds containing shells, and fluviatile beds with reeds, grasses and branches of trees. But he was anxious to reconcile his discoveries with Scripture, and put forward many ideas with that end in view ; ideas sometimes plagiarised by others at a later date.

Quirini in 1676 showed that Noah's flood could not have moved heavy bodies to the extent that was assumed, since Boyle had shown that wave action did not continue to any depth. Quirini also contended that Noah's flood could not have been universal. The period indeed was one of great interest ; new observations involving new philosophical ideas that directly opposed doctrines, as Lyell says, 'sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority.'

We now reach the time when British workers begin to take a more important part in the development of natural science. John Aubrey, Martin Lister, Robert Plot were all men of the very highest repute, but

I can only refer to those who come within the scope of my subject, and Robert Hooke, Martin Lister and John Woodward must absorb my attention. Hooke had applied the microscope to the study of fossils; and, in the first edition of Evelyn's *Sylva* (1664), had described a piece of fossil wood after a microscopical examination. The following year (1665) he published that epoch-making volume *Micrographia*, figuring petrified wood, showing cellular structure, for the first time. The plate is poor, but he claims that by the discovery of its pores he produced a better argument for calling it fir than Stelluti had for calling similar bodies merely earth. Hooke contributed greatly to other branches of the subject, but it was over a hundred and fifty years before his contribution to the microscopical study of fossil plants was advanced to a greater degree. He believed in the extinction of species; that volcanic action and earthquakes had changed the face of the earth, and that these could account for fossils being found in the heart of the mountains, and far above the level of their natural habitat; and that it might be possible to 'raise a chronology' out of these records of nature—fossil shells.[5] He considered that England must once have been in tropical latitudes, and speculated on shifts of the poles to explain that hypothesis. His ideas, indeed, involved crises in nature that appeared no less stupendous than those demanded by the diluvialists. These views therefore were not accepted, nor even given the consideration they really deserved. Lister,[6] in 1673, published 'a description of certain stones figured like plants, and by some observing men esteemed to be plants petrified.' They were really crinoids, but Ray, commenting on them, says that the roots are a strong argument for their being 'pieces of vegetables' and suggests that they were submarine plants. In 1692 La Hire[7] described two specimens of petrified palm trees from Africa. He states 'there are people who say fossils are stones, and have never been other than stones, that resemble organisms, while some say that these fossils are petrified. There is reason on both sides. These two stones, however (referring to the fossil palm trees), are so similar to two pieces of wood that it cannot be pure chance that has produced two bodies so similar to two other specimens of such a different nature. It is evident that these petrifactions are far other than sports of nature that have imitated tree trunks.' He also describes fossil wood sent by Father Duchatz from Ava near Mandalay, Burma, and considers that the wood was petrified by the waters of a nearby river as stated by that priest. This is the earliest reference to the famous fossil trees from the Pegu Series on the banks of the Irrawadi. We can see therefore the belief in the organic nature of *some* fossils at any rate (and in this case fossil plants), replacing the old view.

But the doctrines of John Woodward as enunciated in his *Essay towards a Natural History of the Earth* (1695) so coincided with the philosophy of his times that they were accepted enthusiastically. It is true that, at this time, Burnet's *Sacred History of the Earth* (first published in Latin between 1680 and 1690) had a great vogue as a scientific textbook, although

[5] Hooke, *Posthumous Works*—Lecture, February, 1688.
[6] Lister, *Phil. Trans. Roy. Soc.*, vol. 8, No. 100, p. 6181.
[7] La Hire, *Mém. Acad. des Sciences*, Paris, vol. for 1692, p. 122.

there is practically no scientific observation in the whole work. Burnet studied books, not nature, but his eloquence seems to have made up, in the estimation of his literary friends, for his want of scientific knowledge. Woodward, on the contrary, was a great observer in the field, and was one of the figure-heads of his day, if not always a popular one. His methods for obtaining and recording scientific data are so thoroughly sound that it is difficult to believe they were formulated two hundred and fifty years ago. His questionnaire method of obtaining information, when he could not personally travel to the localities in question, is one of the earliest uses of an important present-day practice in scientific investigations. But his deductions from the data he received were often so incredibly unsound that one wonders at the enormous influence he attained. Accepting Noah's flood as universal, and realising that the fossils obtained in northern Europe, in hard limestones and shales, were very different from the modern-looking Tertiary specimens from the deposits in Mediterranean lands, and very difficult to accept as of organic origin when compared with them, he imagined that the flood must have loosened the very foundations of the earth. He considered 'the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid.' [8] Gravitational segregation, to use a petrological phrase in a totally irrelevant connexion, collected the heavier fossils in the lower and more solid rocks, and the lighter forms in the upper beds. Woodward, therefore, did not deny like some of his contemporaries, Lhuyd, Plot and others, that fossils were organic, thus gaining the favour of his non-scientific friends by his common sense; and he did not antagonise the clerics, for he accepted as an explanation for the occurrence of these fossils an event about the reality of which they were perfectly satisfied. It is small wonder that his theory was hailed with acclamation on all hands. Yet he had personally some misgivings, for he admits that the discovery of shells 'in the most retired and inward parts of the most firm and solid rocks . . . almost everywhere' is enough to make one believe they are 'mere minerals,' especially when found in places 'so deep in the earth and far from the sea, as these are commonly found.' Others were also sceptical of Woodward's views, and Ray,[9] exposing some of the inaccuracies, stated that Woodward 'must have invented the phenomena for the sake of confirming his bold and strange hypothesis.' The hypothesis, however, was too excellent an escape from the *impasse* that geological philosophy had now reached to be relinquished readily.

Palæobotany in the Eighteenth Century.

Among Woodward's most enthusiastic followers was Scheuchzer of Geneva, who translated Woodward's work into Latin, and thus spread his theories through the continent of Europe. With Steno's ideas as well as Woodward's to choose from, it is difficult to understand why

[8] *Essay towards a Natural History of the Earth*, 1695, Preface.
[9] Ray, *Consequences of the Deluge*, p. 165.

Scheuchzer should select the less scientific, but he was by no means the only scientist to be captivated by Woodward. Scheuchzer's chief contribution to palæontology is an *Herbarium Diluvianum* (1709) in which there are many reproductions of fossil plants. Woodward had travelled widely to obtain his information, and Scheuchzer adopted a similar method, constantly seeking for proofs of the deluge, and, to his own satisfaction at any rate, discovering them. Woodward having found, from a study of fossil plants, that ' there is so great an uniformity and general consent amongst them, that from it I was enabled to discover what time of the year it was that the deluge began ; the whole tenour of these bodies thus preserved clearly pointing forth the month of May,' Scheuchzer set out to emulate his avowed leader. In the very first plate and figure of his *Herbarium* he illustrates what he calls an ear of corn (actually it is a crinoid calyx with stem and arms attached). ' Now from the same pit ' (in a slate quarry in Mount Plattenberg, near Matt, Canton of Glarus, Switzerland, from which he had obtained fossil fishes) ' I present an ear of corn, a great rarity of nature, a genuine witness to the Universal Flood, and not only a sign of the event but also of the time it took place.' Its plumpness, and yet its semi-mature condition, like that of certain filberts that were wrinkled and shrivelled, indicated that the flood took place about the middle of May.

Scheuchzer, as has been noted, translated Woodward's Essay into Latin and spread his ideas through Europe. By drawing attention to collecting evidence rather than relying on the criticism of literature, he, like Woodward, did an immense service for Geology. It is precisely by assembling new evidence that criticism must come. Woodward and Scheuchzer were both learned and honest observers. Their evidence might be read differently by their contemporaries, and indeed was so read, but their position had been attained by sound methods, and the popularity of the views they held indicates their reasonableness in the eyes of the general educated world of that day.

The stimulation given to the collection of fossils soon bore fruit, and among the literature dealing with fossil plants in particular we may cite a paper by Leigh (1700) on the Natural History of Lancashire. He figured numerous examples, but considered them all inorganic. Parsons, in 1757, described a collection of fossil fruits from Sheppey made by Mr. Jacob of Faversham, surgeon. He defined what he meant by petrifactions thus : ' By being petrified is meant being impregnated with stony, pyritical, or any other metalline or sparry matter.' In the course of his communication he recalls that Woodward thought the flood began in May, ' and yet this very opinion is liable to some objections ; because altho' fruits, capable of being petrified, from their green state, may be pretty well formed in May here, as well as in the same latitude elsewhere, (and are) in favour of this opinion ; yet there are the stones of fruits, found fossil, so perfect, as to make one imagine they were very ripe, when deposited in the places where they are discovered, which would induce one to think the deluge happened nearer Autumn, unless we could think them the productions of more southern latitudes, where perhaps their fruits are brought to perfection before ours are well formed.'

In the same volume of the *Philosophical Transactions* (1757) Emanuel da Costa described the occurrence of impressions of '*herbae capillares et affines*, the gramineous and the reed tribes; but, however, among them many rare and beautiful impressions undoubtedly of vegetable origin, and impressed by plants hitherto unknown to botanists, are not unfrequently met with.' He also recorded cones in the ironstone nodules of Coalbrookdale. Da Costa accepted Noah's universal deluge, and, as evidence, cited the faults in mineral veins. These, he stated, could not have been the result of partial floods, for, if so, they should contain local plants and animals, whereas the fossils were of organisms from 'the most remote climes from those, where they now lie buried.' He instanced specimens of the Indian reeds—bamboos—from England, rhinoceros bones from the Hartz forest, horns of the moose-deer and elephant from England, and exotic shells from Harwich. Leibnitz, in 1706, thought that some of the fossil plants found in Germany resembled living types in India.

The mystery underlying these observations was explained more naturally by Jussieu in 1718,[10] although his ideas were not accepted. He was certainly one of the first to show that the floras of the Coal Measures and that of recent times were totally distinct, and that the supposed analogues of Coal Measure plants could only be found among tropical forms to-day. To quote his own words: 'These plants are so different from those of Lyons, of the neighbouring provinces, and even of the whole of France, that they seem to belong to a new world . . . and what is still more curious these plants either no longer exist, or, if they do still live, they occur in such distant lands that we should not have known of them but for the discovery of these impressions.' He considered their analogues, as has been stated, to occur in warmer regions in America and parts of India, and, since fossil shells were found along with them, he thought they had been floated to France by ocean currents from the south. Summing up in relation to the ideas current in his day, he says: 'It is not necessary therefore in explaining these fossil plants to have recourse to sports and tricks of nature, nor to palingenesis, as some recent authors think. . . . And when one attributes them to the Deluge one does not see with certainty the impressions of mature and fruiting plants determining the month or season of the Deluge, since these plants came from warm countries where plants ripened before those in this country.' Vallisneri also, in 1721, criticising Woodward's hypothesis, advocated another, namely, that the earth had been originally completely covered with water, the land appearing as the water gradually subsided. Moro in 1740 tried to apply the theory of upheaval of the classical authors to Vallisneri's observations. He really resuscitated Hooke's earthquake hypothesis. Generelli in 1748, in defending Moro's notions, stated that vegetable productions were found in different states of maturity, showing that they were embedded at different seasons, and he explained this by recurring volcanic outbursts. Other workers were collecting and describing specimens of fossils, plants, both impressions and petrifactions,

[10] Jussieu, Antoine de, *Acad. Sciences*, 1718.

as well as animals. Lehmann, for example, collected from the coal measure beds at Ihlfeld in the Hartz, and published a paper in 1756 on *Aster montanus* which he thought had been caught at the flood in full bloom. These blooms were really the nodal sheaths of *Annularia sphenophylloides*. Gesner, in 1758, observed that some fossil animals and plants, like those of Oeningen, resembled the local types, while some were either of unknown forms or resembled those from distant parts of the world. One famous production of this time must be mentioned, namely, Knorr and Walch's descriptions of Knorr's collection (1755–1773). Knorr died soon after the commencement of the work, and Walch is really responsible for the greater part. A résumé of palæobotany to date was given and figures of many plants, petrifactions and impressions. It would be difficult to find more beautiful plates, from an artistic point of view, in the whole literature of palæobotany, but the illustrations are almost worthless for reference, in any endeavour to identify similar specimens. The classification too must be considered quite bizarre. None-the-less it was *a* classification, and, as such, deserves mention. Several works appeared during the latter part of the eighteenth century, the majority of the authors describing, with greater or less precision, the characters of fossil plants; but some, like Fuchsel, were also interested in the geological horizons at which the plants were found, and a few devoted themselves to classification, and correlation of the specimens with living forms.

The labours of these scientists were soon destined to bear abundant fruit. It is true that the whole aspect of geological studies had shifted from palæontology to the wider problems of earth processes. The organic nature of fossils was now unquestioned, but the interest had swung over to the problem of rock formation and rock classification. The Vulcanists, Plutonists and Neptunists now held the centre of the stage; but it almost seems as though the palæontologists had been gathering their forces in order to launch the next attack on the philosophy of the new times. Again the first assault was by means of observations on fossil plants, and it was perhaps in view of this that Brongniart has recalled that the plant kingdom ought perhaps to claim the honour of having forced the abandonment of the ridiculous ideas that attributed these remains of an ancient world to sports of nature and to plastic forces.[11] Blumenbach had been teaching that many fossils, plants and animals alike, must have existed under conditions different from the present, as indeed had been involved in Jussieu's writings many years before. But it was left to Baron von Schlotheim and James Parkinson almost simultaneously, in 1804, and certainly unknown to one another, to draw attention to this aspect of palæontology.

The names of their respective works are practically transliterations of one another. Schlotheim's *Flora der Vorwelt* and Parkinson's first volume of his *Organic Remains of a Former World* each deal with fossil plants; and each emphasise the fact that the conditions under which the fossils had existed were different from those now extant. Schlotheim's is

[11] Brongniart, *Histoire des plantes fossiles*, p. 2.

certainly the better of the two productions, and deals with the flora of the Carboniferous rocks of the Thuringen district. Parkinson's work is more general and ranges through Tertiary, Mesozoic and Palæozoic floras. By this time fossil botany had nearly established itself as a science. The study of these remains during the preceding century had very materially assisted in forcing the acceptance of fossils as organic in origin; in exposing the absurdity of the occurrence of one single Noah's flood, which produced all the surface rocks of the earth at one and the same time; and in showing that the fossil plants obtained from rocks represented accumulations at different times, and under conditions different from the present.

One final paper belonging to this period may be mentioned because of the excellence of the illustrations. The *Antediluvian Phytology* of Artis belied the ineptness of its title. The figures were well executed, and it is, to this day, a reference work in determining fossil plants.

Palæobotany—a Science.

But fossil botany *as a science* was initiated by Adolphe Brongniart when, in 1822, he published a classification of fossil plants, and when the first part of his *Histoire des Végétaux fossiles* appeared in 1828. The sub-title of the latter is illuminating. It reads: Botanical and geological researches on the plants sealed up in the different rocks of the earth.

William Smith's paper, *Strata identified by organised Fossils* (1815), and the works of Cuvier, Lamarck and Brongniart in fossil animal and plant remains, respectively, completely changed the aspect of geology. A knowledge of fossils, and of geology, was no longer the hobby of a few interested naturalists, whose main work lay in other walks of life; but studies under the titles Geology and Palæontology became recognised as parts of the scientific equipment of universities, either as separate departments or under the care of biology.

The study of geology had been enriched, by this time, on its mineralogical and stratigraphical sides, and we may say that nearly every important geological theory had been exploited, or, at any rate, envisaged, if only in an elementary form. Practically every one of these theories had its advocates. There were those who still believed that most fossils were *lusus naturae*; and those who considered most of them of organic origin, without denying that *lusus naturae*, in a different sense, did occur. (To-day we can point to specimens of beekite that will pass muster, at first sight, for nummulites of the type *Assilina*; and others that are perhaps less easily confused with actual fossil genera.) Many believed in great convulsions in the earth, either one or several, and pointed to actual geological phenomena in proof of their contentions: others advocated continuity of known world conditions. Some advanced the efficacy of water, others of volcanic action and earthquakes, to bring about these altered conditions. These workers were, for the most part, ordinary reasonable people, and it was not a question of selecting between a right and a wrong explanation or observation, for like the blind men describing the elephant they were all partly right, and partly wrong. The question became one of probability among all the possibilities that had been suggested. A summation

of observations therefore was now necessary, and a systematic method of collating these observations was wanted. On the mineralogical side this had been, to an extent, accomplished by Werner and his followers. In Botany and Zoology, classification had also been effected, but in Palæobotany the system of classification was still crude. In 1818 Steinhauer[12] described Coal Measure plants in the United States, and, for the first time, used the binomial nomenclature, a course that was followed two years later by Schlotheim in his *Petrifaktenkunde*. Schlotheim[13] and Sternberg[14] had each devised classifications, and Martius,[15] in 1822, published a paper giving reasoned comparisons between fossil and recent plants. Although Martius had an unrivalled knowledge of the Brazilian flora, his knowledge of fossils was not so extensive, and his classification was therefore defective. Artis, in his *Antediluvian Phytology*, 1825, presented a résumé of these attempts at classification, and also added that of Brongniart (1822). His own classification, however, was a modification of that of Martius.

In the introduction to the *Histoire des Végétaux fossiles*, Brongniart discussed yet another method of classification of fossil plants. He used the names of living genera if the fossils could be actually identified with living types, modifications of these names where they were more or less related to living forms, and new names where no such relationship could be established. In other words a modification of the classification of the botanist. His work was a tremendous step in advance, and although he made mistakes (such as classing *graptolites* as *algae*) his work is still one of the outstanding memoirs in fossil botany, and a book of reference for the stratigraphical geologist. The reason is not far to seek, for, to accurate descriptions, he added beautiful and meticulously drawn plates. While his work deals with impressions, and these chiefly of vegetative parts of plants, his classification is based on 'form' similarities, and is not comparable in detail with the classification of the botanist; yet he brought order out of chaos, and has given a classification that is as useful to the geologist as to the biologist. The study of fossil plants had therefore attained a scientific basis, and Brongniart well deserves the title of the Father of Fossil Botany.

A brief digression will not be out of place to ascertain, if possible, the general views of geologists at this date. The end of the eighteenth and beginning of the nineteenth century not only saw the publication of several works in fossil botany, as we have noted, but other branches of science were even more prolific in researches. Werner's teaching was everywhere evident in Geology, Cuvier was probably the chief exponent of Natural History, and the workers in other sciences had no reason to doubt the catastrophic philosophy of these leaders. Hutton and Lamarck were both discredited in their lifetime, and, although they had shown 'the writing on the wall,' it was on the wall of the dungeon, or more

[12] Steinhauer, *Trans. Phil. Soc. Amer.*, vol. 1, 1818.

[13] Schlotheim, *Petrifaktenkunde*, 1820.

[14] Sternberg, *Versuch einer Geognostich-Botanischen Darstellung der Flora der Vorwelt*, Leipzig, 1820–25.

[15] Martius, *De plantis nonnullis antediluvianis*, Ratisbonae, 1822.

appropriately the oubliette of the Castle of Science, and not on that of the banqueting-hall. As a result the guests had little opportunity of realising the true position.

To change the metaphor, when everything seemed knit together in a stable framework, science, religion, social customs, even politics (for they too were more or less stable after the Napoleonic Wars), and the world appeared to be working like a perfect piece of machinery, can we wonder that the 'man with the monkey-wrench' was unwelcome? Poor Lamarck, blind as the result of overwork, but still presenting his ideas through the pen of his daughter, and Hutton, the discredited agriculturalist, exerted little influence on their fellow scientists, let alone the general body of their fellow men. Even Playfair's illustrations of Hutton's views had no large appeal.

The belief in a 'special creation' for each type of plant and animal, and catastrophic disturbances in geological science are absolutely akin. Uniformitarianism and evolution are equally associated. It is not unnatural, therefore, that Lamarck adopted uniformitarian doctrines in his *Hydro-géologie* (1802) while Cuvier rejected them in *his* work. The leaders of geology in this country belonged to the catastrophic school, save perhaps Macculloch, whom Lyell acclaims as his teacher.[16]

A summary of the geological problems of that date (1831) was the subject of Prof. Gregory's address to this Section at our Centenary meeting, and I would now only refer you to that excellent statement for further information. One can see, however, the difficulty Lyell found in the mental atmosphere into which he launched his uniformitarian hypothesis. The idea was contrary to all the tenets held by scientists and the general public. He proved, however, a better advocate than Lamarck or Hutton; but he had to fight against tremendous opposition and inertia. He succeeded by appealing again and again to field observations and a parallel method was required in dealing with fossil plants.

Subsequent to Brongniart's work, the study of impressions, or rather incrustations, of fossil plants was actively pursued on a stratigraphical basis, and the distinction between floras at different geological horizons became more and more evident. Tabulation of results showed the general truth of Brongniart's classification, and it mattered little whether the individual worker considered the plants as special creations or adopted an evolutionary viewpoint. The main object was to obtain records. Time and again these records were used to confute the rising tide of uniformitarian doctrines. Witham, in 1831,[17] was delighted to point out that his fossil trees proved the presence of high types of plants in Lower Carboniferous times; and Hugh Miller, in 1849,[18] puts the case much more powerfully. From a literary point of view Hugh Miller was the most powerful opponent of the 'progressive development' school of thought. He was also an indefatigable field worker, so that, while he made his opponents prove every step they took, it cannot be said that he was an opponent of research. His general attitude seems to be typical of the

[16] *Proc. Geol. Soc.*, 1836, vol. ii, p. 359.
[17] Witham, *Observations on Fossil Vegetables*, 1831.
[18] Miller, *Foot Prints of the Creator*, 1849, p. 201 *et alia*.

workers right up to the beginning of this century; they took the view that evidence must be collected, and it mattered little whether they adopted the theory of evolution or not.

The culmination of this work in Britain, for the time being, came with the publication of Lindley and Hutton's *Fossil Flora of Great Britain* in 1837; but an additional series of figures, prepared under their supervision, was published in 1877 under the editorship of Prof. G. A. Lebour. While not ranking so high as Brongniart's *Histoire des végétaux fossiles*, this *Fossil Flora* is a most important publication, and is the last large work on incrustations published in Britain until practically recent times.

A New Technique for studying Fossil Plants.

But while Artis, Martius, Sternberg and, in particular, Brongniart, and Lindley and Hutton were establishing the classification and description of incrustations of plants, a new method had been devised for the investigation of the internal structure of certain specimens, by the examination of thin sections made from them. I have already referred to the uselessness of many of Knorr and Walch's beautiful plates, because of the want of details of structure, and Hooke's microscopical examinations had also borne no fruit, but when Henry Witham published his two works [19] the attention of the scientific world was attracted to the possibility and importance of studying the internal structure of fossil plants. The history of the method of making thin sections of fossil plants I have already placed before this Section,[20] and there drew attention to the controversy that arose between Nicol and others, as to who originated the method. Jameson, writing as editor of the Edinburgh *New Philosophical Journal* in 1834, says he had long known the method, *and had advocated its use to geologists.* Nicol in the same journal claims he had used the method for fifteen years, and there is no doubt that Nicol *introduced improvements in it*; but there also seems little doubt that lapidaries had used an essentially similar method prior to Nicol. Sprengel also had published, in 1828, a work on fossil plants for which he employed sections.[21] There is no doubt, however, that it was Witham's work that showed the importance of the method. (Henry Witham was one of the first members of the British Association, and was one of the twelve constituting the sub-committee on Geology and Geography at York in 1831.) [22]

The advent of the new technique had more than one consequence. It divided the study of fossil plants into two sections, one biological and the other stratigraphical, but it also led indirectly to what was probably the greatest advance ever made in Petrology. The story is too important to be omitted from this address, although only in a secondary sense can we consider it one of the influences of the study of fossil plants on geology.

[19] *Observations of Fossil Vegetables*, 1831. *Internal Structure of Fossil Vegetables*, 1833.

[20] British Association, Oxford Meeting, 1926, Section C, p. 348.

[21] Sprengel, *Commentatio de Psarolithis ligni fossilis genere*, 1828.

[22] Gregory, Pres. Address, Section C, British Association, Centenary Meeting, London, 1931.

During the years between 1831 and 1858 many sections of fossil plants were made, and collections formed. One of these, including Nicol's collection, was in the possession of Mr. Bryson, Edinburgh. Sections of minerals, as thin as $\frac{1}{50}$th inch, had also been prepared, but the possibilities of the method were not realised until Sorby published his paper *On the microscopic structures of crystals*.[23] In this work he says that, while on a visit to Edinburgh, he saw the ' excellent collection of " fluid-cavities " in the possession of Mr. Alexander Bryson of Edinburgh, who told me he had found some in the granite of Aberdeen. I immediately perceived that the subject could not fail to lead to valuable results when applied to geological enquiries.' To pursue the subject, thin sections of rock were required, and from this beginning sprang the study of microscopic petrology.

A second development from the discovery of the internal structure of fossil plants is the biological aspect. Witham's pioneer work was followed by numerous monographs, and larger works like Lindley and Hutton's *Fossil Flora of Great Britain*. These generally dealt with both incrustations and petrifactions. But there were wide differences of opinion in regard to the correlation of parts and of relationships. Writing in 1871, Williamson says of *Calamites* that Lindley and Hutton had given correct illustrations of the relation of root and stem, ' and yet for years afterwards some of their figures re-appeared in geological text-books in an inverted position, the roots doing duty as leaves ; so far was even this elementary point from being settled.'[24] Brongniart also believed that there were two distinct types of *Calamites*, the one cryptogamic, the other gymnospermous. Similar uncertainties existed in regard to other forms, and it was only after much patient research that the present position was established. One of the most important of results has been the differentiation of the great group of the Pteridosperms, and the recognition of their abundance in Upper Palæozoic times. The story is one of interaction of results obtained partly from incrustations and partly from petrifactions, while the later results, at any rate, have only been obtained by improvements in technique dealing with incrustations. In 1866 Binney described *Lyginopteris* (*Dadoxylon*) *oldhamium* as a plant with gymnospermous affinities. ' It evidently belonged to the genus *Pinites* of Witham, since changed by Endlicher and Brongniart into *Dadoxylon*.'[25] Williamson redescribed the plant in 1873, and drew attention to its fern-like and lycopodiaceous characters, but not the gymnospermous features. Later, in 1887,[26] he concluded that *Lyginopteris* (*Lyginodendron*) ' belongs to the group of ferns ' ; but, in the same paper, speaking of *Lyginopteris* and *Heterangium*, he stated ' possibly they are the generalised ancestors of both Ferns and Cycads. . . .' Stur, in 1883, on negative evidence—the non-occurrence of sporangia on the fronds—excluded certain of the fern-like incrustations in Carboniferous rocks from the fern group, and referred them to cycads.

[23] *Q.J.G.S.*, vol. xiv, p. 454 (1858).

[24] Williamson on the Organisation of the Fossil Plants of the Coal Measures, Pt. I, No. 1, *Phil. Trans. Roy. Soc.*, 1871.

[25] Binney, *Proc. Lit. and Phil. Soc.*, Manchester, vol. 56. Read, 1866.

[26] Williamson, *Phil. Trans. Roy. Soc.*, p. 299 (1887).

Felix, in 1885, suggested that *Lyginopteris* had cycadaceous affinities, and Count Solms-Laubach, in 1887, recognised the existence of types, including *Lyginopteris*, intermediate between ferns and gymnosperms. Williamson even in 1890 held that the balance was towards the ferns, 'most probably belonging to some sphenopterid type.' In 1903 the question was settled definitely by Oliver and Scott [27] when they showed that *L. oldhamium* bore seeds of the *Lagenostoma lomaxi* form. The reality of an intermediate group of Pteridosperms was thus proved. The position was attained by reference to petrified specimens, and also to incrustations, and the search for the male fructifications has gone on, since then, with marked success. Many of the male and female fructifications of these fern-like incrustations have been found ; and new discoveries in technique have materially assisted in these researches. Methods devised by the late Prof. Nathorst, Dr. H. Hamshaw Thomas, Prof. John Walton and Dr. Halle have revolutionised the study of plant incrustations and mummified specimens, so that the weapons now in the hands of the researcher are more numerous than ever before ; and this augurs well for the future.

The story of the *Pteridospermeae* might be repeated in other groups. At our doors, at Rhynie, there is the chert bed which has yielded to Kidston and Lang plants whose structures are so distinct that they must be included in another special intermediate group, the *Psilophytales*. Wieland, Florin and others have shown the existence of the Bennettitalian type in abundance in Mesozoic times. Hamshaw Thomas has proved the occurrence, in the Jurassic *Caytoniales*, of characters that throw considerable light on the probable ancestors of the angiosperms. While it may be objected that these have more botanical implications than geological, there is the obvious reply that anything that has a bearing on the elucidation of past phases of life is, of its very essence, geological. I do not agree that a piece of geological research must necessarily produce a geological map of a piece of country. One of the most pleasant aspects of geological work is certainly that it takes one into the field ; but specialist work in the laboratory is no less geological because it is also biological or petrological or chemical.

Fossil Plants as Stratigraphical Indexes.

The outcome of the stratigraphical aspect of these researches was that there had occurred four distinct floras in geological times, an early Palæozoic, a late Palæozoic, a Mesozoic and a Tertiary flora ; and that there were florules by means of which smaller divisions could be recognised. The degree of accuracy with which these latter may be delimited is still, however, open to discussion. There is some evidence, also, for an early marine flora in pre-Cambrian and very early Palæozoic time, but, though apparently extensive, the types are few and many are possibly only inorganic growths.

As far back as Jussieu's time (1718) a distinction between the plants of the Coal Measures and the living flora had been realised, but no

[27] *Proc. Roy. Soc.*, vol. 71, p. 477.

reasonable differentiation was given until Brongniart, in 1849, suggested that there were three distinct floras in geological time, and named them after the dominant types of plants in each, namely :—

I. Reign of Acrogens . .	(Old Red Sandstone) Carboniferous, Permian.
II. Reign of Gymnosperms .	Triassic, Jurassic and Cretaceous (Wealden).
III. Reign of Angiosperms or Flowering Plants . .	Cretaceous (above Wealden) to present.

We now recognise an older flora in Devonian strata, below the Upper Series, which has lately yielded several new and important types. The recent interest in this older flora was undoubtedly stirred up by Kidston and Lang's monographs on the plants obtained so near to us in Aberdeen, namely, Muir of Rhynie or Rhynie, as it has now become known throughout the world. As regards actual numbers of species this older Devonian flora is poor, but those that are known indicate considerable diversity in organisation. *Palaeopitys* is a type that Hugh Miller [28] classed with the higher gymnosperms, but Kidston and Lang [29] would incline rather to place it with the *Pteridosperms.* The Upper Devonian genus *Callixylon* has very specialised secondary xylem, and an argument might be made, on that account, for some ancestral form, with gymnospermous affinities, in the lower rocks. At any rate the higher and lower pteridophytes are admitted, as also the Psilophytales and the algæ and fungi. In other words, there is a fairly representative phase of vegetation ; and a phase so different from the succeeding phases, that it deserves to rank as a flora of the first order. (May I recall that it was *this* flora that Hugh Miller used so frequently in his geological arguments combating the ' development hypothesis ' as the theory of Evolution was called in his day. The force of the argument is now gone, but it was an important feature in moulding geological ideas at the time.) How far down the geological scale this flora may extend we do not know, but it certainly carries down into the rocks of Lower Old Red Sandstone times.

A yet older flora is found in the early Palæozoic and even re-Palæozoic rocks. The only relics of it consist of the algæ, and the so-called algæ. that abound at certain levels. The algal character of some of these has been seriously challenged ; even some of those now accepted as such may have to be relegated to other categories, but some at any rate can be accepted. Now these are all marine forms, so far as we know, and their very simplicity is a barrier to classification. Are they the lower terms, as it were, of several floras, or did one marine type persist through these prolonged ages ? At present we cannot say. From a geological point of view they are useful as indicating a type of deposit, for plants can only occur in shallow water ; and this affords yet another example of the use of plants in geological philosophy.

[28] Miller, *Footprints of the Creator.*
[29] Kidston and Lang, *Trans. Roy. Soc. Edin.*, vol. liii, p. 415.

It is well to elaborate the fact that many of these so-called algæ may not have been correctly classified. Massive beds of limestone of Permian age near Denver, U.S.A., as Prof. Johnson has shown, have a nodular character that simulates that of algal limestones, but no trace of algal tubes can be found. Even the surface limestones formed as a result of capillary action on the borders of deserts may also show banded and nodular structure very similar to algal growths, as may be seen in the Kalahari desert to-day.

On the other hand, Sir Douglas Mawson [30] records recent 'biscuit' shapes, and nodular structure, in calcareous deposits forming on coastal flats, and beyond any doubt the result of the activity of blue-green algae, and yet no minute algæ structure can be observed.

Aside from these possibilities, algæ of Cambrian, Ordovician and Silurian age of the *Solenopora* and other types have been determined; and the structures in pre-Cambrian rocks are also probably true algæ, in some cases; so that the evidence for a pre-Devonian flora is reasonably good. If, and when, fossiliferous terrestrial deposits of these ages are discovered, we may obtain some of the higher terms in yet another floral series.

But the flora that has been most thoroughly and extensively explored is that of Carboniferous times, and to the late Dr. Kidston of Stirling we owe the present accepted subdivisions; but the work of authors in other lands must not be forgotten, for it has had repercussions on the position in this country. When I mention Grand' Eury, Zeiller, Renault, P. Bertrand, Potonié, Gothan, Renier, Jongmans, Zalessky, David White, I only select a few among the older workers whose influence has been felt here. Kidston recognised six divisions in this country in his latest memoir.[31]

Upper Carboniferous Rocks	Radstockian Series Staffordian Series Westphalian Series (Yorkian Series) Lanarkian Series
Lower Carboniferous Rocks	Carboniferous Limestone Series Calciferous Sandstone Series.

As one of these names (Westphalian) has long been used in a wider sense, Prof. Watts has suggested the use of the term Yorkian, and this has met with general approval. In the past few years the scheme has been criticised, especially by mining engineers, as the zoning possible by using the florules was not sufficiently close for their purpose. They prefer to use marine bands in their work in the Coal Measures. This has led to a rather unjust criticism of the use of fossil plants in geological work. In any sequence an unusual bed will form a useful *datum* line, if it be sufficiently extensive. In a marine series an algal phase is extraordinarily important, as Prof. Garwood has shown; [32] and a marine phase

[30] *Q.J.G.S.*, vol. lxxxv, 1929.
[31] *Fossil Plants of the Carboniferous Rocks of Great Britain*, 1923–25.
[32] *Q.J.G.S.*, 1912; *Geol. Mag.*, 1914; *et alia.*

in an estuarine or lacustrine series would be equally valuable. It happens that the latter types of rock may contain coal seams, and, consequently, marine bands have assumed a very great importance in correlating beds in different areas. But a widespread ash bed would have been quite as useful for mapping.[33] For wider zoning plants *have* proved useful.

But Kidston's classification is not expected to stand as the last word, and already research has shown it defective. Dr. Emily Dix [34] believes that the base of the Staffordian Series should be lower than Kidston suggested; and she finds that, with the line drawn at the lower level, it will more or less correspond with one of the molluscan zones—that of *Anthrocomya phillipsi*. Any classification that will bring diverse groups into accord is of the greatest value. Dr. Dix has made another suggestion that might well be examined carefully. I have stated above that it is the *accidental* character of marine horizons in a non-marine series and the accidental occurrence of an ash bed that give them their value in stratigraphy. Dr. Dix states: '. . . that more attention would have to be paid to the vertical ranges of various species of plants, *and in particular to the occurrence of rare species*, which often give a clue to a particular horizon, before an ideal classification could be made.' This suggestion should be followed up, and the result might remove the odium with which some mining engineers regard fossil plants.

Fossil Plants as Quantitative and Qualitative Indexes.

Another phase of research in plant palæontology is the quantitative type which has been explored along two lines: (*a*) for correlation of strata in a comparatively small area with possible extension over a wider field, and (*b*) for correlation of one and the same coal seam over large or small areas. In 1929 [35] the late Mr. David Davies published the results of many years' work in an area of some 30 square miles in East Glamorganshire. The most distant points were 5 miles apart. He recorded the colossal number of nearly 400,000 fossil plants, and, as a consequence, obtained a very accurate idea of the quantitative balance of plants at different horizons (actually 29) in the Coal Measures of that district. The strata searched were normally the shales immediately on top of the coal seams, but sometimes from 2 to 14 ft. above these seams. On the whole, therefore, the flora, or microflora, is that associated with the individual seams. His results show that the floras ranged from wet to dry types. In the former lycopods (*Lepidodendron*, *Sigillaria*, etc.) predominate, and in the latter ferns and pteridosperms. *Calamites* and *Cordaites* were distributed fairly evenly throughout both types. Molluscan remains (Lamellibranchs) occurred abundantly in association with the lycopods, i.e. the wet type. On the whole the dry floras were the more common, and so he concludes that coal, in these seams, is not so much a swampy as a drier boggy accumulation. I am convinced that a continuation of his

[33] Dr. Ellis has actually used an ash bed, the Frondderw Ash, in mapping the rocks round Bala. *Q.J.G.S.*, vol. lxxviii, 1922.
[34] E. Dix, 'Coal Measures of North Staffordshire,' *Q.J.G.S.*, vol. lxxxvii, 1931.
[35] *Phil. Trans. Roy. Soc.*, vol. ccxvii, 1929.

researches would yield interesting results in what we may call the study of micro-floras, but the work of collecting, naming and recording such great numbers of fossil plants will only attract a worker who has the appropriate opportunities for obtaining the information, and the patience of enthusiasm.

Equal skill and patience was required for the second line of research indicated above. The tabulation and analyses of the relative abundance of fossil spores, in one and the same coal seam, has been used to correlate beds in different parts of the Yorkshire Coal Field. A considerable degree of success has attended the method. Diagrams have been constructed representing the spore index for different types of spores from top to bottom of selected seams, and, as a result, Mrs. G. E. Finn [36] has been able to recognise individual seams of coal over distances of about 40 miles, *and independent of the flora or fauna of the associated rocks.* The method was tested rigorously for the Arley, Better Bed and Silkstone seams with marked effect; and it shows that the spore content and proportion of types of spore to one another can be relied upon for the identification of seams in all parts of the Yorkshire Coal Field.

Still thinking of single seams, the new technique of Hickling and Marshall [37] opens up another avenue for the use of plants in geology. They find that they can identify certain bark structures in *Lepidodendron*, *Sigillaria* and *Bothrodendron* by examining the thin layers of bright coal that often form the surface layer of the specimens. Having identified the types of bark, they go on to examine the layers of the coal itself, and it certainly appears that we may soon know accurately the plants that made the actual coal, whether the bark, wood or spores, and in what proportions they have occurred.

The application of the metallographic method to polished and etched surfaces of coal has also yielded valuable results, as has been shown by Seyler.[38] In these several ways the stigma of uselessness may yet be entirely removed from fossil plants as means of close zoning in the Coal Measures, and as indexes of definite conditions of accumulation of individual seams. The economic consequences may be equally important in the exploitation of special seams.

Nor has the importance of the flora of Carboniferous age been confined to land and swamp plants, the marine algæ have been extensively employed by Prof. Garwood in this country, and by other workers abroad, as zonal indexes. They have been employed as indicators of conditions of depth, and it is extraordinary the extent to which similar lagoon conditions had spread, for example, over the north of England and southern Scotland in early Carboniferous times. Sir Douglas Mawson, as already mentioned, has shown the wide spread of calcareous algæ of the blue-green type over saltmarsh areas in Australia to-day [39]; and this forces one to remember that the mere presence of algæ does not necessarily imply *marine* lagoonal phases. Only when they are associated with actual marine animal forms,

[36] University of Sheffield Library, M.Sc. Thesis, 1931.
[37] *Trans. Inst. Mining Engineers*, vol. lxxxvi, 1933.
[38] *Phil. Trans. Roy. Soc.*, vol. ccxvi, 1928.
[39] *loc. cit.*

or belong to forms that are definitely marine, can their presence be regarded as satisfactory evidence of such conditions.

There is another consideration that requires investigation, and in which fossil plants will assist the geologist. Huge thicknesses of strata of the sedimentary series must have been derived from land-areas, probably of fair elevation to allow the necessary gradient for streams. Were these lands clothed in vegetation ? Examples of upland phases of plant-life are not always easily obtained, but, in association with volcanic action, I believe we have conditions that assist in preserving *some* record of such floras. During Lower Carboniferous times in Scotland, at any rate, the volcanic ashes enclose abundant remains of plant life; and, while we can say little about the actual amount of elevation of the areas concerned, the plants of the *Pitys* type, which were so common, with their short, thick, hairy phyllodes, show an adaptation to a drier environment than that occupied by the *Lepidodendreæ.* The proportion of wood in the axis of these *Pitys* trees also points to conditions where the individual could not depend as much on mechanical support from its neighbours as occurs in swamp growth ; while the growth rings in the wood show, when they occur, responses to some rhythmic influence. These characters all point to *Pitys* as an upland type. The drifted plants of the ' roof ' nodules of the coal seams in England, also, probably furnish examples of an upland flora.

There cannot be a shadow of doubt that the fossil plants of Carboniferous times have had, and still promise to have, important repercussions on our ideas of the geological conditions (including climatic conditions) of that age.

Permo-Carboniferous Floras.

But while the Carboniferous flora in Europe and N. America continued into that of Upper Carboniferous times without any marked change of type, though, of course, with recognisable modifications and additions, there were great changes developed in other parts of the world. The Glossopteris flora has long been known, and its association with clearly marked glacial phenomena has given rise to much speculation. Beneath the beds bearing the Glossopteris flora are rocks containing a typical Lower Carboniferous suite of plants, i.e., when compared with beds of similar age in Europe and N. America. Exact correlation of the strata across the Tethys sea has not been effected, and, of recent years, there has been some tendency to draw attention to the rarer plants in the Glossopteris-Gangamopteris assemblages as illustrating connecting links between the flora in the southern hemisphere, or rather south of the Tethys, and that to the north. It has been suggested also that this flora must have lived in a cooler environment than that in which our Coal Measure plants flourished ; and that a shift of the South Pole to the Indian Ocean would give a distribution of the known localities, where the floras in question occur, such that the northern flora would occupy a more or less equatorial belt and the Glossopteris flora one bordering upon polar regions. Two considerations rather negative such an explanation : (*a*) there is no good ground for assuming that the Coal Measure flora was

a tropical one, and (*b*) if the South Pole were in the Indian Ocean the North Pole would come out in N.W. Mexico, and no sign occurs there of Permo-Carboniferous glaciation. Even on the best arrangement of these localities to suit Wegner's hypothesis of continental drift, some evidence of cool conditions should be found in the rocks of that area; hot, arid conditions, however, are indicated rather than cold.

The mixing of northern types in the Glossopteris floras, as shown by several recent papers, has some bearing upon the question of the complete isolation of Gondwanaland from the northern continents; so also has the discovery of still other floras of Permo-Carboniferous age—the Gigantopteris flora of China and Korea; the Angaraland flora of Siberia; and the Upper Permian flora of the Grand Canyon of the Colorado. But, until more is known of these latter, hypothetical re-arrangements of continents and oceans are rather premature, though, of course, they are interesting exercises of ingenuity. The Gigantopteris flora [40] had an admixture of forms more common in the Mesozoic rocks, as also had the Angaraland flora. The flora of the Grand Canyon deposits,[41] too, had Mesozoic characters. It would be interesting if the quantitative method of David Davies could be applied to all these floras to determine which plants were really abundant, and which were rarities. There is one area at least where this could be done, namely, at Wankie in Southern Rhodesia. Several of us in this room will remember the absolute preponderance of *Glossopteris* on the horizon from which we collected in the field at Wankie in 1929, as well as in the samples brought to us at the Mine Offices through the good graces of the manager. The 'northern forms' were conspicuous by their rarity. It is too much, at present, to expect these intensive studies to be conducted in the areas in question, but such ecological researches will have to be attempted before we can say that these floras may be used as confidently for zonal, or other geological and palæogeographical conclusions, as we can employ the Coal Measure floras of N.W. Europe and Eastern America.

Generally speaking, the Palæozoic floras occupy the greater part of the attention of geologists, and the reason is not far to seek. If fossil plants are to be used at all in zonal work, they must be used in areas where there is a practical demand for such zoning, and where plants are abundant. Now we know that there are coal seams of Mesozoic and Tertiary age of very great extent, and of enormous potential value, but they have not been exploited so thoroughly as the late Palæozoic coals, and consequently the associated floras have not yet received the attention they merit. But the work of du Toit, Walkom, Halle and others is gradually making us better acquainted with these floras.

Mesozoic Floras.

On the other hand, many important results, from a botanical point of view, have been obtained from the examination of the Triassic and Jurassic plants; and the Botany School, Cambridge, has been especially

[40] See Seward, *Plant Life through the Ages*. [41] D. White.

interested in these floras, and must be congratulated for the way its workers have given their energies to these problems. Prof. Seward, Dr. Harris, Dr. H. Hamshaw Thomas, Prof. Walton and others have contributed noteworthy memoirs, not merely describing the plants, but discussing the geological and botanical implications of the floras they have studied. This has necessitated devising new methods of examination, and Dr. Thomas' work in that regard is most valuable. Indeed it has led to recent investigations of Palæozoic fructifications, at the hands of Dr. Halle, that are most illuminating, and that have already been mentioned.

In general terms the Mesozoic floras contain a few survivals from Palæozoic times, but the special development of new forms of ferns, possibly some pteridosperms, cycads, conifers and rare types that may be the percursors, or even the ancestors, of the flowering plants, are the main features of the floras. On the whole, the interest of the Mesozoic floras is botanical rather than geological. So far as I know, no great amount of zoning has ever been accomplished by using these plants. Yet Pia has employed algæ to determine zones in the Alpian Trias.

If the Palæozoic flora has drawn attention to world climates in the past, that of Mesozoic times has accentuated the position. In point of fact it was the discovery of Mesozoic plants in Arctic regions that drew attention to the problem, if not in the first instance, at any rate at an early date. A brief consideration is therefore not only warranted, but imperative, in our study this morning.

In some areas where the Gondwanaland flora has been developed, and particularly in India and Australia, there seems to be a gradual change from the late Palæozoic Glossopteris-Gangamopteris flora into that of Mesozoic times and terminating in the *Thinnfeldia* flora. In Europe the plant series in similar rocks is scanty, and in America enormous numbers of coniferous trees, that are represented in the petrified forests of Arizona and Utah, are derived from *one* horizon—the Chinle formation of Middle Triassic age. In these special areas in India and Australia there are apparent links with the upper Palæozoic vegetation, but our knowledge seems like ignorance, in contrast with what has been discovered in the Coal Measure flora. Much more work is necessary.

It is the Jurassic-Lower Cretaceous flora, however, that has attracted most attention in botanical circles; for it is a phase that was suddenly replaced by one closely similar to that of the present time, and yet one that was itself quite distinctive. Perhaps the most striking character is the number and variety of plants of the cycad class. But it was a complete plant phase, with all the main groups represented, and even the flowering plants are heralded in the *Caytoniales* of the Yorkshire deposits.

The Rhætic flora has been brought to our notice recently by the wonderful suite of plants of this age from Greenland. The flora in general shows a considerable development of ferns of the *Osmunda* type, numerous cycads and other gymnosperms, among which the Ginkgoales (*Ginkgoites*, *Baiera*, etc.) are specially prominent, and the genus *Sagenopteris*, which Dr. Thomas has shown probably bore fruits that are a first approximation to those of the flowering plants. In the later Jurassic rocks distinctions

like those that could be detected in different areas among the older suites of plants, cannot be seen—the associations from widely separated places are very similar ; and there is decidedly less difficulty in assigning specimens to their proper botanical group. Plants of doubtful affinities are fewer. Thus lines of evolution can be traced, as, for example, in the Osmundaceæ and the Bennettitales. The last group has been of special interest, and the works of Dr. Wieland, Prof. Seward, Dr. Marie Stopes and Dr. H. H. Thomas have illustrated the wonderful variety of form included in it. Indeed it might be called *the* distinctive group of Mesozoic times, though the Ginkgoales also constitute another very prominent group.

The physical conditions under which some forms lived can sometimes be detected. The swamp flora can be seen in association with coals like the Brora coal, *Equisetites* is a common type ; the estuarine series in Yorkshire yield a flora that has drifted probably from lowland regions ; and the conifers and cycads illustrate plants from a rather drier, and possibly upland, environment. In this connexion the Portland and Purbeck beds are specially interesting to the geologist. Drifted stems of cycads, and logs of coniferous wood, are not uncommon in the Portland quarries ; but the curious rings of tufa deposited round erect stems, as seen at Lulworth, probably point to lagoonal conditions of slow subsidence and gentle laving of the stumps by waters rich in calcareous material. An explanation of the well-known breccia beds of that last-mentioned locality, as due to deposition over thick accumulations of plants that subsequently rotted and caused the over-lying strata to be broken up, need not detain us, except to express our doubt of the suggested solution. The water of these lagoons was frequently evaporated to dryness, as the conspicuous rock salt and gypsum pseudomorphs attest. This is merely a local point of interest, but several of us here visited the area during the British Association meeting at Southampton, and it recalls to me pleasant memories of our discussion of the Jurassic flora on the spot.

The Lower Cretaceous Flora.

The plants of the upper Jurassic beds are generally similar to those that occur in the beds of Lower Cretaceous age, but a transition into the Tertiary flora is evident in the latter almost from the start. Heer compares the Greenland beds of the Kome series with the Wealden series, the Atane series with the Cenomanian succession. The latter view has been favourably accepted, the former not ; but, taking the Cretaceous flora in Greenland as a whole, Seward [42] regards it as representing more fully than elsewhere the transition between the Mesozoic and Tertiary floras. As a rule the comparison of late Cretaceous and Tertiary floras with living plants shows differences of geographical distribution and conditions, rather than essential differences in types. Dr. Stopes also has shown that the angiospermous woods from the Lower Greensand Series [43] did not exhibit any primitive characters, nor any relationships with gymnospermous (cf. *Bennettitales*). They were ' like quite highly

[42] *Phil. Trans. Roy. Soc.*, vol. B., p. 215 (1926).
[43] *Phil. Trans. Roy. Soc.*, vol. B, p. 203 (1912).

placed Angiosperms in all their details.' Thus the Upper Cretaceous-Tertiary flora must have been preceded by one in which highly developed angiosperms were not uncommon, and the suddenness of the institution of the later flora must have been due to some factor that allowed the angiosperms scope, and inhibited the other elements in the Lower Cretaceous flora. What the factor was we do not know, but the suggestion that it was the 'Cenomanian transgression' is one of great value. Berry [44] thinks it 'futile to speculate about the problem at the present time,' and advocates a more intense study of Mesozoic floras, especially in the tropics, and the upland rather then the swamp flora. There is much in this criticism, and I would further add that the volcanic ashes of these days should be searched for traces of this upland flora.

Nevertheless the suggestion that the 'Cenomanian transgression' was responsible for the alteration of conditions that gave the angiosperms the 'boost' which initiated their present dominance is, I think, valuable and worth exploring. It happens to coincide with an idea I have held since I first stood on the edge of the Colorado River, at the bottom of the canyon, and looked at the sand and mud that was being swept along. One of my difficulties, at the time, was to understand the conditions of deposit of the Greensand, Gault and Chalk formations in England. Prof. E. B. Bailey [45] had just published his suggestion of the Chalk being produced off a desert coast, and the desert conditions persisting after the beginning of Tertiary times. I found it difficult to reconcile the abundant plant remains of the upper beds of the Lower Greensand, and even of the Gault itself, with desert shores. But the geography of the Colorado River seemed to explain the situation. The river passed through areas of barren, desert country, and areas with abundant vegetation, carrying sand from the one, plants from the other, down to its estuary. Such a stream might be expected to produce a kind of deposit like the Greensand with smooth-grained, current-bedded sands, and abundant plant remains. A depression of the drainage area up to the desert zone would widen its estuary, prevent sand from being swept into the areas once reached, and permit the accumulation of only fine clays or only pelagic deposits in these areas. The succession of plant-bearing, current-bedded sandstones would be followed by clays and calcareous oozes comparable with the succession of the Upper Cretaceous rocks in S.E. England; and the shores might be deserts during the production of the calcareous oozes, and so permit the latter to accumulate close in-shore. After elevation, the desert conditions might still persist.

But suppose the land prior to depression was clothed, in its non-desert track, with a vegetation consisting of an older flora holding in check, by competitive power, a younger race; or, to put it into actual fact, a Mesozoic flora, similar to that found elsewhere without angiospermous associations, but here competing successfully or, at any rate, holding a balance with its angiospermous units.

The depression of such a land would cause the flora to migrate, and

[44] 'Revision of the Lower Eocene Wilcox Flora,' U.S.G.S. Prof. Paper 156, 1930, p. 11.

[45] *Geol. Mag.*, 1924, p. 102.

the accession of water to the desert region would permit of some increase in rainfall over the area. The land would therefore be ready for plant colonisation, but each element of the flora would have more or less an equal chance, and the more vigorous race would prove successful. It is in some such way I picture the conditions to the north and west of Britain —in Greenland if you will—during late Cretaceous and early Tertiary times.

To an extent this will also account for Greenland as one distributing centre for the angiosperms at a later date ; and, in addition, the depression would encourage the chance of ocean currents from the south rendering the climate rather warmer during the later stages than during the earlier. In fact it would explain the climatic conditions in England up to the time of the London Clay deposits.

The Tertiary Floras.

While there is some admixture of the Tertiary and the older Mesozoic flora to be observed in one or two localities, on the whole the change comes with dramatic suddenness. So sudden, indeed, that attempts at possible explanations appear futile, for there is no evidence of any comparable change in *inorganic* nature. Examination of the sediments deposited before and after those of the zone in which the change is observed do not indicate any cause for the phenomenon, nor can the corresponding igneous rocks, if available, give us any clue. But, and this, so far as we are concerned, is the most important feature of all, *the whole basis of classification of the fossil plants is also changed.* This point is simply not appreciated by the average geologist, and, for that matter, it seems to have been tacitly ignored by the palæobotanist. What would we say to the mineralogist who classified minerals by their colour ? It *could* be done ; it *has been done.* That was the basis of Werner's classification, and we find men like Jameson defending it. Now there is no doubt that such a method would, now and again, be accurate—*azurite*, *malachite*, etc., have distinctive colours—but what faith would we have to-day in mineralogical conclusions based on such a scheme ?

The classification of flowering plants is based on floral characters and fructifications—this is the result of the combined experience of botanists—and these characters depend on delicate structures produced at a particular season of the year, generally totally different from the vegetative parts of the parent plant, and developing in a very few days into a fruit that is also totally distinct from the other members of the plant that bears it. While the two end stages—the vegetative body and the seed—may be fairly persistent over a period of months, the flower may last only a few hours. Yet the floral characters are the basis of botanical classification. The chances of preservation of such delicate structures are very few (though they occasionally are found, as in the fine ashes of the Miocene Lake, Florissant, Colo.), and the chances of correlation with their parent plants are still fewer. With what are we left ? The vegetative structures, definitely rejected by the botanist as bases of classification of flowering plants ! We cannot get away from this position, that, as a matter of observation, the vegetative parts of flowering plants are not safe criteria

for classification. Here and there a plant may have characteristic vegetative features, just as minerals may have characteristic colours, but taken by and large, the basis is as defective as classifying minerals by their colour alone. Modern methods for the determination of cuticular structure certainly improve matters as regards leaves and very young shoot tips, but they also are deficient, despite the work of many observers. I hope I may not be mistaken—I have said flowering plants. The case for gymnosperms is rather better; we may place some confidence in *their* determination by vegetative characters, but not flowering plants. For this reason we have more confidence in the determination of members of the older floras by vegetative characters, though caution is also necessary in these cases.

Unfortunately the very abundance of flowering plants, and their absolute preponderance numerically over other types, in the Tertiary floras *from the very beginning* is a hindrance, not a help, to their use in geological work. The determination and naming of the specimens is not easy, and the protest made by Mrs. Reid and Miss Chandler in their recent memoir [46] is timely in this respect, for workers are far too prone to give the name of a living genus to a specimen, and leave one to read down the description before one sees that their determination has been made on a few scraps that were hardly recognisable. Berry long ago protested against the *nomina nuda* in tertiary floral lists; Reid and Chandler's protest against the use of definite names for indefinite specimens is no less deserved; and Sahni's statement [47] regarding the Mesozoic flora that 'it is satisfactory to note that the hostile ranks of the species *incertæ sedis* have suffered heavy losses' cannot be taken as a matter of congratulation when applied to some lists of Tertiary floras.

If workers refrain from giving the name of living types to fossils that merely look like them, and designate such with some name less committal, their floral lists would command more respect, and fewer unsafe deductions would result, to the great benefit of geology and of our colleagues in other sciences who are coming more and more into the field of geological philosophy as we draw nearer to recent times. I refer particularly to the geographers, meteorologists, and archæologists.

Yet there are certain generalisations that may be accepted. (1) The earlier Tertiary floras contain angiosperms almost exclusively of arborescent type—a feature of tropical and sub-tropical vegetation to-day. (2) The circum-polar spread, in early Tertiary times, of so many forms now living in tropical and sub-tropical lands indicates that these types were developed in the colder regions and migrated southwards, and not the reverse. (3) There is evidence that some rise in temperature in the north temperature zone in N.W. Europe and N.E. America took place about middle Eocene times, and that from that 'peak' there has been a progressive lowering of temperature, with oscillations during the recent Ice Ages. (4) The Tertiary floras of the Northern and Southern hemisphere are not quite comparable for, while there appear to be considerable variations in the northern hemisphere, there is a greater uniformity in

[46] *The London Clay Flora*, p. 46 (1933).
[47] *Proc. Asiatic Soc. Bengal*, Presidential Address, 1922.

the southern hemisphere. How far this is the result of inadequate collections or inaccurate determinations is difficult to ascertain.

Fossil Plants and Special Rock-types.

It is not my purpose to discuss the origin of coal, oil-shale, ironstone, limestone, etc., that are the result of the accumulation of plant debris or a consequence of the activity of plant life in the past, but a recent publication by Murray Stuart makes such a direct correlation of definite fossil types with oil formation in Burma that some comment is merited. The fossil wood first described by La Hire in 1692 consists chiefly of pieces of *Dipterocarpus* stems, and the living *D. turbinatus* is the source of the Garjan oil of commerce, a single tree yielding, on occasion, 40 gallons of oil per annum.[48] Murray Stuart[49] suggests that the petrifaction of the trees now found in the Irrawaddi Series released the oil now accumulated in the underlying Pegu Series. The theory of the origin of oil from vegetable material is no new one, but such a direct relationship has never before, I think, been suggested, nor can it be accepted without further investigation.

Fossil Plants and Climate.

On account of the clearly marked zonal distribution of plants to-day, it has long been held that they should be good indexes of climatic zones in past time. The position in this regard is not so definite as was formerly maintained, when the continents and oceans were held to be fairly permanent in position, though not necessarily in size or shape. Migrations of plants were considered to be effected slowly and in consonance with climatic changes. This was especially so in relation to the Tertiary flora and to the Ice Age. But the discovery of many floras in Arctic and Antarctic areas, and several Ice Ages, has compelled re-consideration of the whole position. The other discovery, that oceans and continents had probably not occupied the same relative position with respect to the poles as they do to-day, further complicated matters.

In a recent discussion at the Royal Society[50] Prof. Seward put the case from the botanical point of view and stated that plants have been over-estimated as indexes of climate. As regards the older floras, he stated that the plants were of little value, because they were extinct. One of the arguments that used to be advanced for a tropical climate during the accumulation of the Coal Measures in England was the large size of some of the specimens. Last autumn I had the opportunity, through the good offices of Prof. Fearnsides, to examine and photograph probably the largest Carboniferous plants ever seen. They were casts of the stems of members of the *Lycopodiales*, and their stools ranged up to 6 ft. 3 in. in diameter, or 20 ft. in circumference. Slightly smaller specimens in the same vicinity had been described by Sorby[51] and are still protected by wooden huts erected round them. Now members of this relatively lowly plant group reaching the enormous size of forest trees must, according

[48] Watt, *Dictionary of Economic Products of India*, vol. iii., p. 164.
[49] *Inst. Pet. Tech.*, 1925, p. 296: *Geology of Oil, etc.*, 1926.
[50] 'Discussion on Geological Climates,' *Proc. Roy. Soc.*, ser. B, vol. 106, 1930.
[51] *Q.J.G.S.*, 1871.

to the ideas of the time, have grown under tropical conditions. There is no *a priori* reason, however, why this should be the case. Luxuriant growth is not a feature exclusively tropical, it is more a question of water supply at the proper time. Still less can we accept the contention when we find that the luxuriant Glossopteris flora, co-existing with the northern one, was associated with glacial conditions; the glaciers, in places, coming down to sea level. Tropical conditions in the northern hemisphere at the same time as glacial conditions in the southern, simply could not be brought into unison. The explanation by Wegener's hypothesis of continental drift is an easy way out of the impasse; but this is only one case among several, and even Wegener would hardly have accepted the wanderings of his continents that would be required to explain all the known occurrences.

Again, the presence of plants, whose living relations inhabit tropical lands, in the early Mesozoic rocks in Greenland is no proof of tropical conditions in Greenland at that time, for a genus of plants may have *some species* capable of enduring more rigorous conditions than others, and, moreover, there may be a progressive decline in the power of certain genera to withstand any but tropical conditions as time goes on. Prof. Seward further pointed out that the present diversity in floras is largely due to the great preponderance of flowering plants, and that the apparent uniformity in past floras was therefore illusionary.

Then we must never forget that fossil plants are almost always 'form' genera and 'form' species, and that, even within a single genus to-day, we may have some species confined to tropical regions and others that tolerate a colder climate. Consequently, a specimen that cannot be accurately proved as identical with a living species may be little or no use as a climatic index.

Of course when specimen after specimen points in one and the same direction, so far as probable climatic characters are concerned, then we cannot disregard that indication, and when such indications can be confirmed by collateral phenomena, such as an apparent sub-tropical flora and entire lack of tundra features in a region now in the tundra belt, the conclusion is inevitable that climatic change has taken place.

Taking everything we know into consideration, the general consensus of opinion is that plants *do* afford an index of climatic changes, and that these changes have been very considerable in past times.

Can we explain those changes, and can we obtain an explanation that will not conflict with other evidence?

In the past few years interest in the problem has been awakened by Wegener's theory of continental drift, or, perhaps better, the modification of Wegener's hypothesis suggested by the late Prof. Joly of Dublin. Yet it must be remembered that Lyell and Darwin [52] were considering the problem seventy years ago, so that it is no new geological puzzle.

[52] *Lyell's Letters.* Letter to Darwin, March 10, 1866. 'I have been doing my best to do justice to the astronomical causes of former changes of climate, as I know you will see in my new edition [*Principles of Geology*], but I am more than ever convinced that the geographical changes are, as I always maintained, the principal and not the subsidiary ones.'

The most valuable contributions towards a solution are coming at present from the meteorologists, and Dr. Simpson and Dr. Brooks have each made important suggestions. There is, as Dr. Simpson says, 'no formulated meteorological opinion,' but he has personally come to a certain conclusion.[53] Throughout geological time, he continues, there must have been climatic zones. The climate in a zone depends on two factors—the intensity of solar radiation, and the distribution of land and water. A study of the present climatic zones shows that the mean temperature in it is not affected by the distribution of land and water, though locally a range of 5° C. from the mean of the zone may occur. It is the annual range of temperature that is chiefly affected by the distribution of land and water. On these grounds he concludes that 'no change in the distribution of land and sea alone could have produced the large changes in climate shown in the geological record.'

Increases in solar radiation will cause (*a*) a greater temperature gradient from pole to equator, (*b*) an increase in the general circulation of the atmosphere, (*c*) increase in cloud and rainfall, (*d*) an increase in the mean temperature of all zones. Again he concludes that there is no evidence of sufficiently large changes in solar radiation to account for the facts of geological climates. Consequently, only a theory of continental drift will suffice.

Dr. Brooks thinks that Simpson has under-estimated the effects of ocean currents. He attacks the problem from another point of view, namely, the question of Ice Ages. He shows that once an ice cap commences, it spreads rapidly, for its cooling effect increases with its area; but a critical point occurs beyond which the effect is not proportional to the area, and consequently the ice cap finally terminates. He concludes then that the conditions that determine the temperature of Arctic and Antarctic areas is not the distribution of land and water, but the distribution *if there were no ice*. The most favourable distribution of land and water for high polar temperatures is a series of long narrow islands extending meridionally from high to low latitudes, and separated by wide deep seas. The worst distribution would be lands stretching parallel to the lines of latitude. There are, in his opinion, only two possible polar climates, a mild type and a glacial type. Since the lands have mostly stretched from high to low latitudes, the mild type is normal and glacial periods exceptional.

Wilhelm Ramsay, of Helsingfors, in 1924[54] advocated an increase in relief to explain glaciations, as others had done in former years. Orogenic movements, he claims, have preceded the chief periods of glaciations. The Caledonian, Hercynian, and Alpine periods of orogenic disturbance have each resulted in glaciations in the succeeding epochs. Mountain chains increase radiation because the layer of air above them is thinner, consequently there are colder conditions developed, and snow may accumulate, causing a still further reduction of temperature. Again, the greater amount of snow involves a removal of water from the ocean, and the lowering of level may amount to as much as 130 metres if we

[53] 'Discussion on Geological Climates,' *Proc. Roy. Soc.*, 1930.
[54] *Geol. Mag.*, 1924.

accept 1,000 metres as the thickness of the ice sheet—a figure not incompatible with known observations of former ice sheets. Ocean currents would be checked, and still further increase of the ice cap would result. Depression of the lands, however, would have the reverse effect. Beyond any doubt, periods of mountain building and of marine incursions have occurred, but Ramsay admits that there are difficulties that he cannot fully explain. His theory is, however, only a development of that put forward by Lyell in his letter to Darwin, and later published in his *Principles of Geology*.

Now all these theories abound in conditional phrases, and the geologist hardly knows what to accept. Personally I favour Brooks' theory, for it demands far less disturbance of the conditions we are inclined to consider normal. The earth so far as we can see has always been solid and rotating at an enormous rate—a gyroscope, in fact. If we are to assume wholesale melting of the sub-surface rocks, then the speed of rotation would soon play havoc with the crust. It would no longer be a case of continental 'drift,' there would be a continental 'surge.' I cannot accept such wholesale continuous movements of continents as Wegener envisages, but I do accept something along the lines of Joly's periodic local softening of the sub-stratum, differential foundering of the continental blocks, even slow separation of the continents, and a rotation of the blocks round parts where softening had not taken place. In consequence, the continents are not aggregated round the equator, where they ought to be on Wegener's hypothesis, and there has not been any serious slip of the skin on the core—Wegener's definition of shifting of the poles—at any one time. The Atlantic I consider a young ocean, but, like Tate Regan,[55] believe that it was a wide ocean by Eocene times. In fine that the so-called tremendous earth storms are really very local. It is true that the 'Alpine' storm of Miocene date looms very large in north-west and central Europe, but look *on a globe* at the area involved and see how small it is relatively—a mere trifle as compared with the opening up of the Atlantic ocean. I feel that our maps have much to do with our defective appreciation of world conditions. Mercator has a deal to answer for, as a result of his 'projection,' and until we get back to studying a globe, instead of a sheet of paper, our ideas will remain distorted, especially when the areas involved are in the temperate and northern regions—precisely those regions where geological research is most abundant to-day.

Now how are we going to test these several hypotheses? One of the neatest possible tests has been applied by Mrs. Reid and Miss Chandler in their work on the London Clay Plants.[56] This flora has puzzled people since Parsons' work in 1757. (We may say that the presence of *Nipa* at Sheppey and *Artocarpus* in Greenland are two of the most difficult palæobotanical facts to arrange in their proper setting.)

These ladies set out, first of all, by establishing the principle that with flowering plants, at any rate, and confining their attention to living forms, the great bulk (70 per cent. at least) showed little power of adaptability to different climatic zones—they are tropical or extra-tropical as

[55] 'Discussion on Geological Climates,' *Proc. Roy. Soc.*, 1930.
[56] *London Clay Flora*, British Museum, 1933.

the case may be. The remainder show extraordinary little power of adaptability—a species here and there may do so, but not the bulk. They quote H. H. Thomas[57] 'that there seems to be no indication in the geological record of any gradual acclimatisation of the plants which existed in Eocene times in Europe as the Great Ice Age approached, and the climates became colder, and, presumably, also drier.' As regards the flora they were studying—the London Clay flora—not a single genus that lived in Britain survived into Upper Pliocene times. They therefore conclude that the bulk character of a Tertiary flora *does* determine its climatic character, and that that of the London Clay *is* sub-tropical. The presence of *Nipa*—the most northerly record so far—gives them a temperature figure, and they ask both Simpson and Brooks whether they can supply such conditions in Britain. The temperature is that of a wet tropical forest—a lower figure than the normal tropical type—a mean annual temperature of 70° F.

Simpson could only supply it by the aid of some measure of continental drift which Mrs. Reid and Miss Chandler could not accept. Brooks could only give that temperature with the aid of Simpson's hypothesis of increased solar radiation, and increase of cloud and precipitation. But the plant evidence could be explained by Brooks' hypothesis; or, expressed otherwise, accepting plants as good indexes of climatic zones, an appropriate zone temperature could be established in Britain during London Clay times by the application of a theory devised to explain glacial and non-glacial epochs. If further tests, from the distribution of other plants, were applied we might obtain sufficient information to determine which theory is the most satisfactory. Brooks' hypothesis appeals to me because it does not demand increases in solar radiation over long periods. But increases for short periods I think are necessary to explain climatic rhythms that are known, and that can be traced back in the history of certain trees. I do not regard Brooks' and Simpson's theories as mutually exclusive, but as mutually complementary.

Fossil Plants and Climatic Rhythm.

Recent researches in archæology in Africa and America, and also former discoveries in other parts of the world, have drawn attention to minor fluctuations in climatic character similar to those periodic cycles that meteorologists had also discovered from quite other considerations. Historical records, so far as they go, can be checked up; but these are of short duration from a geological standpoint. In regions of the world where trees had not been destroyed, either by man or other agencies, certain examples have reached a great age—several thousands of years; and, if plants are good indexes of former conditions, here, if anywhere, is an opportunity to obtain a cross check on historical information, and a possible extension into pre-historic times. The work of Antevs[58] and A. E. Douglas[59] on annual rings and their variation according to climatic

[57] 'Discussion on Geological Climates,' *Proc. Roy. Soc.*, 1930.

[58] *Amer. Jour. Sc.*, vol. ix, p. 296 *et seq.* (1925).

[59] Carnegie Inst., Washington, vol. xi, no. 289 (1928). *Brit. Assoc. Report*, Bristol, p. 371 (1930).

changes, or accidents (forest fires, etc.), is most illuminating. Now palæontologists had noted the possibility long ago, Witham, Lindley and Hutton and the earlier writers on the internal structure of fossil plants had noted, and discussed the implications of, the fact that in Palæozoic times certain specimens of one and the same species might have rings in the wood, while others might not. Unger in 1847 noted that Mesozoic woods (Lower Triassic) had poorly developed rings, and therefore concluded that the equable climate of Palæozoic times was becoming periodic; but later workers, Arnold, for example, have proved that in *Callixylon* from Upper Devonian rocks, rings were quite well developed, and consequently the climate of Palæozoic times was not equable.

Botanical research shows that one and the same species may or may not have rings, depending on the conditions in which the specimens were growing. This, in some cases, depended on whether the plants were growing in warm or cold places, but, in others, on whether the climate was equable or not, and quite irrespective of any particular climatic zone. The reaction was to environment, but not necessarily to seasonal changes. In other words, the rings are difficult to interpret. But some plants are specially sensitive to these changes, and plants in temporate regions—or at the higher elevation in tropical lands—nearly all have these rings. Conifers have the most distinct rings, in general, and even *Araucaria*, where they are not so marked, produces rings under varying conditions of nutrition. Now conifers have a long geological range, and so might possibly indicate seasonal rhythm in past times; or even indicate, by breaks in the rhythm, some exceptional occurrences that might be rhythmical or not. Antevs [60] after recalling all the difficulties and the need for caution, has stated, 'We can say with certainty that the occurrence of very marked zones in Jurassic woods from Spitzbergen, and the lack of rings in Jurassic woods from British East Africa, indicates marked climatic zones and pronounced annual periodicity in Jurassic time.' Douglas made a very careful study of the 'Big Trees' in the Sierra Nevada and other areas in America, and concludes that any 'index' tree must be very carefully selected, and the results checked not merely in the immediate vicinity, but consistent records must occur further afield. He found that the best index tree is the Yellow Pine, and the next best the Scotch Pine. *Sequoia gigantea*, while more complacent to changes than the others, is longer lived, and the records from these trees may go back to 1,000 B.C. with consistent results over a considerable area.

While geologists will not benefit much from these researches directly, yet meteorologists and archæologists will, and a cross check on de Geer's results from Varve counts in Scandinavia, or similar results in America, may yet be effected. The age of ancient ruins at Gobernador Canyon, Aztec, and Pueblo Bonito, Chaco Canyon, Aztec, New Mexico, have been ascertained by examination of the ring record of logs which still retained their bark, and which had been used in building these dwellings. This was done by reference to large trees in the area, and a count back until the ring record of the log and that of the 'index' tree coincided.

[60] *Amer. Jour. Sc.*, vol. ix, p. 300 (1925).

Douglas has also proved rainfall records at Flagstaff, Arizona, at eleven year periods for 600 years, and this checks up with the known solar record.

Though we cannot entertain extravagant hopes that this mode of research will help geologists, we may learn something of periodic occurrences in the past. It is true that at present single trees are little use, but methods may yet be found for using the records of such single trees. The largest fossil tree I know, and I think it is the largest yet discovered, is a stump said to be of the *Sequoia* type and of Miocene age at Henderson's Ranch, near Florissant, Colorado. It is $17\frac{1}{2}$ ft. in diameter, and 10 ft. high, quite comparable in girth, therefore, with the Big Trees of to-day. A record of its rings should be made, as also of those of at least a dozen other stumps in that area. Then again the 'petrified forests' of Arizona, Egypt, Burma, and elsewhere should also be recorded. The game might not be worth the candle, but it might add yet another minor link to the chain of ideas with which fossil plants have affected the philosophy of geology.

SECTION D.—ZOOLOGY.

THE STUDY OF BEHAVIOUR

ADDRESS BY

E. S. RUSSELL, O.B.E., D.Sc.,

PRESIDENT OF THE SECTION.

In his Presidential Address to this Section last year, Dr. James Gray put forward the view, with which I entirely agree, that the organism has properties and potentialities as a whole which are not reducible to the properties shown at the chemical level. He maintained that 'the conception of the organism as a single living entity is or should be the more peculiar attribute of experimental biology.' We should study not only the action of the parts in isolation, as does the physiologist, but also and more particularly the activity of the animal as a whole. Thus we should not rest content with a knowledge of the mechanism of muscular contraction or of the propagation of the nervous impulse; we must study also and before all the action of the neuro-muscular system as a whole, as, for example, in locomotion—and, I would add, in behaviour generally.

I propose to continue the discussion so ably begun by Dr. Gray, and to deal particularly with that whole-activity of the organism which we call its behaviour.

The study of animal behaviour has been somewhat neglected in this country, and this is all the more regrettable since first-rate pioneer work has been done by Prof. C. Lloyd Morgan and the late Prof. L. T. Hobhouse. Furthermore, it has been largely divorced from the general study of zoology, and handed over to the physiologist and the psychologist, neither of whom is, as a rule, sufficient of a naturalist to appreciate the full biological significance of the behaviour observed in the laboratory. It is of course obvious that an animal's behaviour is one of the most important things about it, and if the zoologist wishes to understand how his animal lives, maintains itself, and carries on the race, the first thing he should study is its behaviour in the field. It is also clear that a thorough knowledge of the bionomics or ecology of the animal is quite essential for the interpretation of its behaviour in the experimental conditions of the laboratory.

We are meeting to-day in a zoological department which has always recognised the fundamental importance of the study of behaviour and

ecology. Its head is Professor of Natural History, and both the present occupant and his predecessor, the late Sir John Arthur Thomson—to whom I personally owe so much—have made great contributions to the study of that subject which Prof. W. M. Wheeler has so aptly called ' the perennial root-stock or stolon of biological science.'

Interest in natural history is—fortunately—still widespread among zoologists, both professional and amateur, and one of the most significant developments of recent years has been the vigorous growth of the Oxford school of animal ecologists, under the leadership of Mr. Charles Elton.

But while excellent work in the field of scientific natural history is being done by the animal ecologist, the economic entomologist, the fishery worker and also by the amateur naturalist, they have not as a rule taken what one might call a professional interest in the problems of animal behaviour, though they have accumulated a great store of observations which are of the highest value to the professional student.

Generally speaking, as things are at present, the study of animal behaviour as a science has not in this country taken its rightful place as an essential part of zoology, either in research or in teaching ; the tendency has been to treat it either as a branch of physiology or as an adjunct to psychology, and in both cases to turn it into a laboratory subject.

When we inquire into the reasons for this unsatisfactory state of affairs, we find, I think, that one of the main causes is the influence upon biology of a certain metaphysical theory which we inherit from the seventeenth century. We owe to the great thinkers of that age, and particularly to Descartes, a particular view about the nature of reality which has become firmly rooted in our thought and is apt to bias our methods of research. I refer of course to the classical doctrine of materialism, with its absolute separation of matter and mind.

How did this doctrine arise ? We do not find it in Aristotle. The dualism of matter and mind was foreign to his thought. A primitive form of materialism had been propounded by the Ionians, and Anaxagoras had added to their cosmology the conception of a universal reason or ' Nous.' But Aristotle accepted neither view. He worked out a system of his own, which is now somewhat difficult for us to grasp, for we have lost that freshness and directness of approach to the great problems which were his. We know that he spoke of the nutritive, the sensitive and the rational ' souls,' which formed a hierarchy of functions, but, with the possible exception of the rational soul, he did not think of these as separate from the body. His view was not vitalistic in the modern sense ; it did not imply a dualism of matter and entelechy ; for Aristotle, ' soul ' was an expression for the total functional activity of the organic unit, for its activity as a whole.

We do not find the clear-cut dualism of matter as extended substance and mind as inextended thought fully expressed until we come to Descartes many centuries later.

Descartes stands on the threshold of the modern world. No man can

be independent of his epoch, and Descartes was in some respects a direct heir of the Middle Ages ; he shared their preoccupation with reason and the soul of man. He was primarily a mathematician and a theologian ; he had unlimited faith in the power of the human intellect ; he was concerned to demonstrate the existence of God, and to uphold the belief that man's soul is immortal, that he is not as the beasts that perish. At the same time, he was profoundly influenced by the physical and cosmological conceptions introduced by Copernicus and Galileo, and grasped their enormous significance. He was acquainted with the work of his great contemporary, William Harvey, on the circulation of the blood, and made great play in his books with a somewhat crude attempt to explain all physiological processes mechanically. It was he who imposed dualistic materialism upon biology as its working method.

Although nowadays modern physics has completely transformed the old conception of matter, and has little use for the notion of material determinism, it is not so long ago that materialism was the orthodox creed of science, and we are in biology still suffering from the after-effects. I do not think I can better describe the fundamental tenets of this creed than by quoting a passage from T. H. Huxley's essay on *The Progress of Science*, which appeared in 1887. ' All physical science,' he wrote, ' starts from certain postulates. One of them is the objective existence of a material world. It is assumed that the phenomena which are comprehended under this name have a " substratum " of extended, impenetrable, mobile substance, which exhibits the quality known as inertia, and is termed matter. Another postulate is the universality of the law of causation ; that nothing happens without a cause (that is, a necessary precedent condition), and that the state of the physical universe, at any given moment, is the consequence of its state at any preceding moment. Another is that any of the rules, or so-called " laws of Nature," by which the relation of phenomena is truly defined, is true for all time. The validity of these postulates is a problem of metaphysics ; they are neither self-evident nor are they, strictly speaking, demonstrable.' [1]

As a counterpart to this abstract concept of matter as extended substance we have the concept of mind as inextended thought. Physical science, and here I include physiology, has never known quite what to do with mind. In practice it has ignored mind, and treated it as an ' epiphenomenon ' accompanying, but not influencing, certain physiological processes taking place in the central nervous system.[2] For the practical purpose of research it has treated the animal as a mechanism, and sought to analyse its working in detail. This theory, that the animal is to be regarded, from the point of view of science, as a physiological automaton, we find explicitly stated by Descartes nearly 300 years ago in his *Discours*

[1] *Method and Results*, London, 1893, pp. 60–61.

[2] *Cf.* Huxley : ' The consciousness of brutes would appear to be related to the mechanism of their body simply as a collateral product of its working, and to be as completely without any power of modifying that working as the steam-whistle which accompanies the work of a locomotive engine is without influence upon its machinery.' *Ibid.*, p. 240.

de la Méthode, and it has been for long a guiding principle of research in the physiological study of functions and behaviour.

Let me give you a modern example by quoting a passage from Pavlov's book on *Conditioned Reflexes*, published in 1927. 'Our starting point,' he writes, 'has been Descartes' idea of the nervous reflex. This is a genuine scientific conception, since it implies necessity. It may be summed up as follows: an external or internal stimulus falls on some one or other nervous receptor and gives rise to a nervous impulse; this nervous impulse is transmitted along nerve fibres to the central nervous system, and here, on account of existing nervous connections, it gives rise to a fresh impulse which passes along outgoing nerve fibres to the active organ, where it excites a special activity of the cellular structures. Thus a stimulus appears to be connected of necessity with a definite response as cause with effect' (p. 7). We could not wish for a clearer statement of the underlying assumptions of the stimulus-response (S-R) theory of animal behaviour, nor for a clearer acknowledgment of its source.

It was Descartes, then, who imposed upon European thought for at least two centuries, and upon biology for much longer, that 'bifurcation' of Nature into matter and mind which has raised so many insoluble problems for philosophy, and diverted biology from its true method. As to its effect on philosophy, let me quote a great modern philosopher, Prof. A. N. Whitehead, who writes: 'The seventeenth century had finally produced a scheme of scientific thought framed by mathematicians, for the use of mathematicians. . . . The enormous success of the scientific abstractions, yielding on the one hand *matter* with its *simple location* in space and time, on the other hand *mind*, perceiving, suffering, reasoning, but not interfering, has foisted on to philosophy the task of accepting them as the most concrete rendering of fact. Thereby, modern philosophy has been ruined. There are the dualists, who accept matter and mind as on equal basis, and the two varieties of monists, those who put mind inside matter, and those who put matter inside mind. But this juggling with abstractions can never overcome the inherent confusion introduced by the ascription of *misplaced concreteness* to the scientific scheme of the seventeenth century.'[3]

Actually, instead of being the most concrete of realities, both matter and mind are highly abstract concepts, the product of the reflective intelligence working upon the data of immediate experience.

There is given in individual experience only the perceiving subject and his objective world. This dualism does not correspond, is not synonymous with, the dualism of matter and mind. Subjective experience as we know it directly is a function of organism, not of pure mind; objective experience is a relation between organism and other processes or events. The concept of matter is arrived at by abstracting from the data of sense, by leaving out the 'secondary qualities' such as colour, smell and sound, and retaining the so-called 'primary qualities' of

[3] *Science and the Modern World*, Cambridge, 1926, p. 70.

resistance and extension, with location in time and space. By accepting this abstract definition or concept of matter, we substitute for the objective world of perception a symbolic or conceptual world of discrete material particles, which we may call the ' world of matter.' This world of matter the materialist takes to be in some sense more real than the perceptual and colourful world from which he has derived it. Actually it is less real, less concrete. It is important to remember that the world which we perceive through the senses, with its shapes, colours, smells, tastes and so on, is not identical with the conceptual ' world of matter ' ; we do not perceive ' matter ' at all, any more than we perceive mind ; we perceive things or relations or events.

Complementary to this abstract material universe is the concept of mind as an inextended, immaterial, thinking entity, and this also is derived by abstraction from the data of immediate experience, and principally from the subjective aspect of experience.

As applied to biology, this abstract dualism has saddled us with the theory that the organism is a machine, with the pale ghost of a mind hovering over its working, but not interfering. What chance is there for a real science of animal behaviour if this metaphysical view is accepted ?

Obviously from the Descartian standpoint behaviour becomes a subject for the physiologist to study from his analytical point of view ; he must regard behaviour as the causally determined outcome of the working of the animal machine, under the influence of external and internal stimuli, and he must seek to determine the elementary physico-chemical processes out of which behaviour is built up. The physiologist as such can have nothing to do with mind, and hands over its study to the psychologist, who finds that he can know nothing directly about the minds of animals. Hence we get the state of affairs I alluded to at the beginning of this address—the study of animal behaviour split up between physiology and psychology, with no possibility of a connecting bridge. The scientific study of behaviour thus becomes divorced from natural history and ceases to take its rightful place as an integral part of zoology.

Aristotle knew better than this ; he regarded life and mind as continuous one with another, and the basis of his zoological system was the form and activity of the animal as a whole. But then Aristotle was a first-rate field naturalist and observer.

At this stage you may perhaps object that all this discussion of metaphysical notions is beside the mark and futile. You may say that as zoologists we are concerned only with facts and not with metaphysical theories. You may—quite rightly—point out that in our practical researches we deal with the objective world of perception, and not with the abstract ' world of matter.'

But, unfortunately for us, these metaphysical notions which most of us have absorbed almost unconsciously from the older tradition of philosophical thought have influenced and continue to influence our aims and our methods in practical research. It is impossible to be an absolutely unbiased observer, an exact mirror of the flux of events ; our conscious, and even more our unconscious, preconceptions lead us inevitably to

select from the panorama of objective appearance those facts which are of interest from our own particular point of view, and so to devise our researches as to obtain answers to problems which we impose upon Nature rather than Nature upon us.

Thus if we are firmly convinced that all events are ruled by strict mechanical causality we naturally look upon the organism as a machine, and when we study the behaviour of an animal we seek to analyse it into a number of simple constituents, such as tropisms and reflexes, which are determined by simple and measurable external stimuli. We lean inevitably towards the stimulus-response theory of behaviour—a purely physiological and analytical view—and our researches are based on the supposition that this theory is true. Hence we tend to overlook facts which do not fit into this scheme—we miss them simply because we are not looking for them.

The point I want to get clear is that the Cartesian doctrine of the dualism of matter and mind is in no sense an inevitable deduction from experience ; one is not forced to accept it as the necessary foundation of biological research ; other foundations are possible, as we shall see in a moment.

I have in my preceding remarks purposely exaggerated to some degree the contrast between the physiological and the psychological attitude towards the study of animal behaviour, in order to bring out clearly the logical consequences of accepting the metaphysical theory of the dualism of matter and mind. But I do not mean to assert that all work on animal behaviour can be definitely labelled either as physiology or as psychology in this limited sense. An escape from the dilemma has in practice been found, and this alternative method we shall now proceed to discuss.

Let us first of all try to rid our minds of the abstract notions of matter and mind, and regard the activities of living things without metaphysical preconceptions. As zoologists our job is to study animals in action. Let us try to approach our task with the same directness and *naïveté* that Aristotle showed when he laid the foundations of our science. Instead of assuming a priori that the physico-chemical or analytical method of approach is the only possible and the only fruitful one, let us try the alternative of considering first the most general characteristics of the organism as a whole, and working down from the whole to the parts, rather than up from the parts to the whole, as is the more usual method.

Taking this simple and direct view of living things, abandoning theory and accepting the obvious facts at their face value, we see first of all that the complete phenomena of life are shown only by individuals, or organised unities. Sometimes these units are combined loosely or closely in unities of higher order, as in social insects and in colonial animals, such as corals, but these cases hardly affect the main thesis that life is a function of individuals. There is accordingly no such thing as ' living matter,' save as part of an organised unity.

The second thing we note is that all living things pass through a cycle of activity, which normally comprises development, reproduction, and senescent processes leading to death. This life-cycle is in each species a

definite one, passing through a clearly defined trajectory, admitting of little deviation from normality ; it takes place generally in an external environment which must be normal for the species, and as a rule the internal environment also is kept constant round a particular norm. The activities whereby the needs of the organism are satisfied and a normal relation to the external and the internal environment is maintained, may be called the maintenance activities of the organism, and they underlie and support the other master-functions of development and reproduction.

Our general definition or concept of organism is then an organised unity showing the activities of maintenance, development and reproduction, bound up in one continuous life-cycle. A static concept is inadequate ; time must enter into the definition ; the organism is essentially a spatio-temporal process, a ' dynamic pattern in time,' as Coghill aptly calls it.

Now all these activities are, objectively considered, directed towards an end, which is the completion of the normal life-cycle. One is tempted to use the word 'purposive' in description of these activities, but this term is used in many senses and has a strong psychological flavour about it, so I shall use instead the neutral word *directive*, which I borrow from Myers.[4] It is quite immaterial from our simple objective point of view whether these directive activities, or any of them, are consciously purposive. The directiveness of vital processes is shown equally well in the development of the embryo as in our own conscious behaviour.

It is this directive activity shown by individual organisms that distinguishes living things from inanimate objects. The peculiar character of this directiveness, its orientation towards a cyclical progression of organisation and activity, clearly distinguishes it from the static directedness of a machine, constructed for a definite purpose. It should be noted too that the living thing shows a certain measure of adaptability in completing its life-cycle, so that the end is more constant than the way of attaining it.

Now from this point of view, which is, I maintain, strictly objective, behaviour is simply one form of the general directive activity of the organism ; it is that part of it which is concerned with the relations of the organism to its external world. Plants show behaviour in this general sense just as much as animals do, but they, being for the most part sessile and stationary creatures, respond to the exigencies of environment, and satisfy their basic needs, mainly by processes of growth and differentiation, and only exceptionally by active movements. Thus the dune plant seeking water grows an enormously long root which burrows down through the sand till moisture is reached. Animals on the other hand respond to environment and satisfy their needs by means of movements, either of the body as a whole or of certain organs. But sessile animals, like plants, may also respond or show behaviour by means of morphogenetic activity. The hydroid *Antennularia*, for example, if

[4] C. S. Myers, *The Absurdity of any Mind-Body Relation.* L. T. Hobhouse Memorial Lecture, Oxford and London, 1932.

suspended in the water may send out 'roots' or holdfasts to regain contact with the bottom.

Behaviour, whether of plants or animals, is thus to be regarded simply as one form of the general directive activity which is characteristic of the living organism. It holds no privileged position; it does not require 'mind' as an immaterial entity to explain it.

I tried to show in the earlier part of this discourse that both 'matter' and 'mind' are abstract notions, of little real use in biology, and I maintain here that the concept of 'organism' as I have attempted to define it is a more concrete one, and a more useful one, for the practical purposes of biological research.

If we accept this view of organism, which is to my mind a simple generalisation of fact, we escape or elude the difficulties of dualism; we need no longer regard behaviour as either the mechanically determined outcome of the material organisation of the body, or the result of the activities of an immaterial mind or entelechy influencing in some utterly mysterious way the mechanical workings of the body. By taking as given and as fundamental the plain objective characteristics of the living and intact organism, by refusing to split it up into matter and mind, we avoid both materialism and its counterpart vitalism.

This is, as I conceive it, the central position of the modern organismal theory—the substitution of the concept of organism for the concepts of matter and mind. The concept of organism, or more generally of organised system, may of course be applied right down through the inorganic realm, wherever organised unities are found. Thus a molecule is an organised system, and so also is an atom. I do not, however, agree with those who think that all real unities, both organic and inorganic, are adequately characterised as 'systems.' In certain most general characteristics an atom and a living organism agree, for both are systems or wholes. But the living organism has characteristics which are lacking in inorganic systems, and it can be adequately defined or characterised only by reference to those peculiarities which we have just considered—the weaving together in one cyclical process of the master functions of maintenance, development and reproduction. These distinguish it from any inorganic object or construction, from any inorganic system. Underlying these characteristics is the general directiveness of its activities, their constant drive towards a normal and specific end or completion.

It will be noted that this organismal view makes no real distinction between life and mind, between vital activities and those which in immediate experience appear as mental or psychical activities. In this respect we hark back to a pre-Descartian mode of thought, and call Aristotle our master.

Simple observation shows us that living animals exhibit activities which are obviously not, on the face of them, those of a mechanism. Many of their behaviour actions are strictly analogous to those which in immediate experience we should describe as psychological. Thus we see animals trying hard to achieve some aim or end—a salmon struggling to surmount a fall, for example, or a cat using all its skill to catch a bird.

We do not know whether these actions are consciously purposive or not, but we cannot dismiss the objective facts of striving merely by assuming that they are mechanically determined. There are the facts ; animal behaviour is predominantly directive, or in an objective sense purposive, and there is no use closing our eyes to it.

It is well known too that many animals can learn and profit by experience. Thus if you train a puppy to play with a ball, this becomes of functional significance to it ; it will go and look for its ball, which it remembers ; and other objects of a similar size or shape acquire for it the functional value of a ball, and are used in play. There is here definite evidence of memory, or retentiveness.

In the same way, there is abundant evidence that animals perceive their surroundings, singling out those objects and those events that are of importance in relation to their needs. Of course we cannot know what the quality of these perceptions is, but we *can* determine by suitably planned experiments just what it is to which the animal responds, and we often find that the response is to patterns or images or relations, and not to a simple summation of physico-chemical stimuli. I shall give some examples of this later on. At this stage I merely wish to make the point that from the organismal standpoint there is no difficulty in assuming that animals perceive and react to an external world of their own ; here, as in our own case, perception may be regarded as a function of organism, not of ' mind.'

This is essentially the attitude of ordinary common sense. In practice we treat our fellow men and at least the higher animals as being real individuals with perceptions, feelings, desires, similar to our own. And common sense is in principle justified, though of course it runs a great risk of reading human motives, human ways of thought, into the behaviour of animals, and of assuming without sufficient warrant that their perceptual worlds are the same as ours. But because there is a danger of faulty interpretation, due mainly to inaccurate or inadequate observation, we are not thereby compelled to throw over the general conception that the animal organism is capable of perception, conative behaviour, and memory, if the facts of observation lead us to this conclusion. I do not mean that we should explain behaviour as being due to psychological functions labelled conation, perception and memory—that would be an empty and barren explanation. We are concerned only with behaviour, not with the subjective experience of the animal, which cannot be the subject of scientific study. But we must describe the behaviour fully and adequately, using if necessary terms of psychological implication, refusing to be bound or hampered by the metaphysical notion that the animal is merely a machine or can be treated as such.

In affirming as we do that the animal organism in its behaviour shows a kind of activity which cannot be adequately described in terms of material configuration we are taking no great risk. Our own immediate experience is there to assure us that in one case at least the organism certainly does perceive, strive, feel and remember.

One point more before we go on to consider very briefly how the

organismal method is to be applied in the practical study of behaviour. It is sufficiently clear, I think, that behaviour is an activity of the organism as an intact and unitary whole. Once we begin to tamper with the organism we get something less than behaviour. The 'spinal' dog still retains the power to carry out many and complex reflex activities—and it is quite unimportant whether these activities are unconscious or not—but it does not and cannot manifest the full range of activity which characterises the intact dog. Pursuing the work of analysis further, we can get down to the study of an isolated muscle-nerve preparation, or to the study of the conduction of the nervous impulse and the mechanism of muscular contraction. Here we shall find little or no behaviour in the sense of directive and adaptable activity, and we may reasonably hope to arrive at an adequate physico-chemical account of what goes on. There seems no reason to doubt that a physiological treatment of the isolated parts of the organism may in principle be adequate. But by taking the parts in isolation, we abstract from their relations to the whole, particularly their temporal relations, and we leave out of account just what is fundamentally important—the working together of all the parts in the directive activities of self-maintenance, development and reproduction.

When we analyse a total organic event or process we break up the spatio-temporal unity of the action into little unconnected bits which are unreal in the sense that they are abstract, being deprived of their constitutive relations to the whole process. If for the sake of enlarging and deepening our knowledge we analyse organic activities in detail, we must correct the abstract picture so obtained by re-integrating the part in the whole—we cannot reconstitute the whole action by simple summation of the actions of the parts separated out by analysis.

While then analysis is a justifiable and useful procedure, we cannot hope to build up from the parts thus isolated the directive activity of the whole, which shows characteristics belonging to none of the parts. Accordingly, the study of behaviour is not reducible to physiology or the causal-analytical investigation of the parts. Physiology may profitably consider what are the conditions necessary for the manifestation of whole-properties, and we have an excellent example of this in Lashley's work [5] on the relation between learning and retentiveness on the one hand and the amount of brain substance on the other. But we must work down from the whole to the parts, and the study of the whole, as in behaviour, cannot be adequately replaced by the study of the parts in isolation.

It is possible of course to abstract from the directiveness and continuity of organic events, and to consider the organism over a short period of time as being a mechanism or configuration. It is then susceptible of study and interpretation in physico-chemical terms, just as is an inorganic object, but what we get is physics and chemistry, not biology. A good deal of what ranks nowadays as experimental biology is not biology at all, but physico-chemical research carried out on organic systems

[5] K. S. Lashley, *Brain Mechanisms and Intelligence*, Chicago, 1929.

with complete disregard for the distinctive characteristics of such systems.

From our organismal point of view, the study of behaviour is neither comparative physiology nor comparative psychology ; it is the study of the directive activity of the organism as a whole, in so far as that activity has reference to the organism's own perceptual world. It must start with what Lloyd Morgan calls the ' plain tale ' of behaviour, the full and accurate description of what organisms do, and of what they are capable. Though plants also show behaviour in this general sense, and their whole-response to environment is a proper subject for study, it will lighten our discussion if we limit it to the behaviour of animals.

The plain tale description of animal behaviour must begin with a study of the natural history and ecology of the animal. Most animals are restricted to one definite and rather specialised kind of environment ; they are adapted both in structure and activity to inhabit some particular ecological norm or ecological niche. We must discover by field observation how the animal finds this ecological niche to begin with, and how it maintains itself therein. We must investigate how it counters changes in its environment, how it defends itself against enemies, how it finds or captures its food. All this is straight natural history in the old sense, the study of the ' habits ' of animals, and it is linked up closely with the modern study of ecology. It is the necessary basis for the more detailed study of behaviour. It is also the clue to much of the behaviour shown in the artificial conditions of a laboratory experiment.[6]

Clearly then we must start with direct observation of the animal's behaviour in the field, or in experimental conditions that approximate as nearly as possible to the normal. We must then ask what is the animal trying to do, what is the objective end or aim of its action ? Sometimes the animal is doing nothing in particular ; it is resting or merely waiting for something to turn up. Usually, however, the animal is active, is showing behaviour ; its actions are directed to some end, are aimed at satisfying some need, and we can determine by observation and experiment what that end is ; the sign that the end is attained is the cessation of the train of action. Thus, to take a very simple example, if you remove a caddis larva from its tube, by the simple method of prodding it gently from behind with the head of a pin, it will move restlessly about until it finds the empty tube. Then it will enter the mouth of the tube head first, creep through, and perhaps widen the narrow hind opening of the tube, but it will finally turn right round inside the tube so that its head comes out at the front end, and it is then able to get about normally. The aim of the train of behaviour is attained—normal relations to environment are restored. If you have removed the tube so that the larva cannot find it, it will achieve its end by another means, provided the materials are available, for it will then construct a new tube. That is an example of simple directive behaviour, and it also illustrates the general rule that the end is more constant than the method of reaching it.

[6] E. S. Russell, *The Behaviour of Animals*, London, 1934.

We find very often that a simple directive activity is part of a general directive process of long range, which may take months to reach its goal; and to understand the simple action we must relate it to, or integrate it in, the general process of which it is a part. Take for instance the building of a nest by a bird. This taken by itself is a directive activity, aimed at the construction and completion of an adequate brooding place for the eggs and young. It is a fairly stereotyped and specific activity, but unusual materials may be pressed into service if the normal materials are hard to come by. But nest-building is simply one link in the long reproductive cycle, which may commence with migration, and its relation to that cycle, which includes both behavioural and physiological activities, must be studied if we are to understand it fully.

This illustrates the general rule of biological method which we have just discussed—that the whole life-cycle of activity must be regarded as the primary thing, and that the parts of it which may be isolated for study must be re-integrated in the whole-activity. The human mind is prone to analysis, and we must be on our guard against its inveterate tendency to separate and distinguish parts or elements in what are, fundamentally, continuous processes.

In thus relating partial events to life-cycle, we must of course consider above all their time-relations, not only their relations to what has gone before, but also and more particularly to what follows after. I should like to refer in this connection to a recent address by Coghill, in which the organismal view of development, including the development of behaviour, is set out with great clearness and authority. He tells us that 'the neuro-embryologic study of behavior shows that events within a behavioral system can be understood scientifically only as their relation is known to subsequent as well as to antecedent phases of the cycle. The antecedent tells a part of the story about the present, but not all of it; for within the present are events that have behavioral significance only in that which follows. . . . The purely scientific method, dealing exclusively as it does with space-time relations, can not reject the future from its explanation of the present in behavior, because any event in an organismic cyclic system is an integral part of both the future and the past.' [7]

We come now to the question, how is behaviour instigated or initiated, how is it set going? There is one ready-made answer to this question—that behaviour is essentially an automatic response or reaction to stimulation, either external or internal. You will recall the passage I quoted from Pavlov earlier in this address, in which the stimulus-response theory is very clearly and explicitly set forth. According to Pavlov, stimulus is related to reaction as cause to effect; the impulse generated by the stimulation of the receptor organ is automatically transmitted along the appropriate nervous pathways to set in motion the appropriate effector organ. Behaviour is therefore completely determined by the stimuli

[7] G. E. Coghill, 'The Neuro-embryologic Study of Behavior: Principles, Perspective and Aim.' *Science*, lxxviii, 1933, pp. 137–138. I have expressed a similar view in my *Interpretation of Development and Heredity*, 1930, pp. 170–171.

and by the connections already existing in the nervous system or built up during the formation of conditioned reflexes.

There is no time, and no need, for me to criticise this view in detail. Actually the strict theory of connectionism is rapidly breaking down in face of the facts established by the brilliant work of Lashley on the one hand and the Gestalt psychologists on the other. I will merely point out, first, that this analytical and physiological view is a pure hypothesis, derivable from the Cartesian metaphysics, and second, that it does not harmonise well with the simplest facts of observation.

Nothing is more striking than the apparent spontaneity of animal actions, their independence of the immediately present external stimulus. When an animal is hungry it goes and looks for food ; when a hunting wasp requires provisions for her future offspring she actively seeks high and low for the proper caterpillar or spider that she needs ; when a bird is building her nest she looks everywhere for the grass or feathers or moss she requires. As Koffka well expresses it : ' While reflexes are typically " passive " modes of behaviour, which depend upon the fact that some stimulation has taken place, instinctive behaviour is, by contrast, significantly " active " in its search for stimuli. The bird *seeks* the material for its nest, and the predatory animal stalks its game. In other words, the stimulating environment is not a sufficient cause for these activities. Every movement requires forces which produce it ; but the forces that produce instinctive activities are not in the stimulus-situation—they are within the organism itself. The *needs* of the organism are the ultimate causes of its action ; and when these needs have been satisfied, the action comes to an end.' [8]

A very great part of the behaviour of animals is, quite simply, response to needs (or deviations from normal), and not to direct external stimulation. When a starfish is turned on its back it tries in various ways to right itself, or, more accurately, to re-establish contact with a solid surface. Careful study of the action by Fraenkel and others has clearly established that the real ' stimulus ' to the action, if one may use the word stimulus at all, is not something positive, but simply the lack of contact between the tube-feet and some solid object, the need to re-establish a normal functional relation to the substratum. No doubt in all cases of action directed towards satisfying a need introception comes into the story, but the broad fact remains that it is lack of normality, or the absence of some condition necessary for maintenance or development or reproduction, that sets much of behaviour going.

I do not, however, wish to over-emphasise the autonomy of behaviour, its independence of external stimulation. It is certainly true that behaviour is to a considerable extent influenced by events in the animal's environment which it perceives and to which it responds. Thus all animals react to danger or to signs of danger by appropriate behaviour. Some like the rabbit bolt for their burrows ; others like the squirrel take refuge up a tree ; the antelope trusts to its fleetness, and most birds to

[8] K. Koffka, *The Growth of the Mind*, 2nd edit., London, 1928, p. 103.

their wings. Some animals find safety in immobility, or in the protection afforded by a hard shell or carapace, or an armour of spines; the tube-worm retracts its tentacles like a flash and may close the tube up with a stopper.

In many of these cases the animal responds not to an actually nocuous stimulus but to some sign of approaching danger—to a shadow, the cracking of a twig, or to any object looming up and drawing near. So, too, the feeding response is often elicited not by direct contact with the food itself, but by a sign of it—its smell, its movement, the disturbance it makes.

This leads us on to consider a point on which I touched before, namely, the nature of the perceptions, especially the visual ones, to which the animal gives significant responses. This is a field in which much interesting and important work has been done of late years.

It has been shown in many cases that it is not the separate physico-chemical stimuli that are important in eliciting response, but the whole complex of stimuli taken together, their arrangement, their pattern, their relations to one another and to the visual field as a whole. A dog can recognise his master by sight, and it does not matter whether he sees him full face or in profile, standing up or sitting down, close at hand or a little way off. There is a general pattern or facies, with infinite variation in detail, to which essentially the response is made. He would be a bold man who would propose a connectionist or additive explanation of response to a varying and shifting pattern or image of this kind.

Then there are the many examples known where response is made not to a particular visual datum *per se* but to it in its relations to other features in the perceptual field. The simplest cases are those of 'relative choice,' exemplified by Köhler's experiments with chicks. He first of all trained them to respond to the darker of a pair of grey colours. He then substituted a new pair of colours, consisting of the darker of the old pair and one still darker. He found that his chicks now reacted, not to the original grey, but to the darker of the new pair. They had really been trained to respond not to a particular shade of grey but to the darker of a pair. Many similar cases are known.

Here is an observation by Bierens de Haan [9] which shows in a striking manner how an animal may respond to an object only in its relation to other objects in the visual field. A young Pig-tailed Macacque was given the choice of two doors, one marked by a card with a red circle, while above the other was placed a card bearing a blue triangle. Food was placed behind the door with the red circle, and the monkey rapidly learned to choose that door. The experimenter then substituted for the blue triangle a blue circle or a red triangle, and he fully expected that the monkey would continue to choose the red circle. Instead of that the monkey was completely confused, and chose the red circle in only about fifty per cent. of the trials. When the blue triangle was restored, however, it responded correctly and consistently. It appeared from these

[9] *Animal Psychology for Biologists*, London, 1929, pp. 40–41.

experiments that the monkey had learned to respond not to the red circle by itself but to it in combination with the blue triangle—that is, to the correct member of a complex comprising these two sensory data.

The whole trend of modern work on the perceptions of animals is to show that they do not normally respond to simple physico-chemical stimuli, but to more or less complex whole-situations, and if to parts of the whole-situation, then to these parts in their relation to the whole. This is the essence of the principle of Gestalt—response to elements in the perceptual field as parts of the pattern of the whole. The principle of the whole is thus valid for the perceptual field just as it is for executive behaviour.

These few examples of modern work on the perceptions of animals emphasise the need for extreme care in establishing exactly what it is in the surrounding world to which animals respond. We must not assume *a priori* that behaviour is determined by a concatenation of simple physico-chemical stimuli; we must drop all metaphysical theory and try to find out by careful experiment just what animals do respond to. We shall often find that they respond to images or patterns, or to classes of objects that have for the animal the same functional significance, or to bare relations.

Response to relations is clearly demonstrated in some very thorough work recently carried out by Klüver[10] on the perceptual world of monkeys. His general method was to train his monkey to draw in one of a pair of boxes differing in some particular, for instance in weight. When he had established a positive response to the heavier of a pair, he varied the difference between the boxes, using two others of quite different weights from the original pair. He found by this method that his monkeys would respond to the bare relation 'heavier than,' quite irrespective of the absolute weight of the boxes used, provided of course that they were not too heavy for the monkeys to move. Other experiments of the same type showed that the monkeys had a power of practical generalisation, that many objects differing in shape and colour yet produced the same response—they were, from the monkey's point of view, functionally equivalent. This method of studying the equivalence or non-equivalence of perceptual objects promises to be a very fruitful one for investigating the behaviour of animals.

In the short compass of this address I have been unable to give more than the very slightest sketch of a method for the study of animal behaviour which is, I think, likely to be the method of the future. It is, I maintain, a perfectly objective method, dealing with observable fact, and it is free from any metaphysical preconceptions.

I have been concerned to point out two things. One is that it is time biology shook itself free from the limitations imposed upon it by a blind trust in the classical doctrine of materialism. This doctrine is not in harmony with the modern development of philosophical thought, nor with the modern development of physical science, and it is not well adapted to the study of living things.

[10] H. Klüver, *Behavior Mechanisms in Monkeys*, Chicago, 1933.

We must adopt a more concrete and more adequate concept of the living organism, one that will take account of its essential characteristics. We must think of the organism as a four-dimensional whole, or directive cyclical process, and no longer attempt to contain it within the static scheme of the classical materialism. This does not lead to any form of dualistic vitalism. The relation of behavioural or 'psychological' activities to physiological is not the relation of mental to physical activities, but is, quite simply, the relation of a whole spatio-temporal directive process to its parts.

SECTION E.—GEOGRAPHY.

CO-OPERATIVE RESEARCH IN GEOGRAPHY; WITH AN AFRICAN EXAMPLE

ADDRESS BY

PROF. ALAN G. OGILVIE, O.B.E.,

PRESIDENT OF THE SECTION.

Ever since our subject was re-established as an organised discipline, the essence of which is the study of terrestrial distributions and their inter-relations, geographers have been sifting and collating data of extremely varied character. The facts which have thus been incorporated in the body of geographical literature have themselves usually been established by workers in other fields, while geographers have drawn deductions from them, in many cases without having the opportunity to test their validity on the ground. As a result generalisation and causation in regard to very large sections of the continents must necessarily rest on a rather insecure foundation. The question therefore arises—how can this be remedied ? The world is large and complex, while the number of geographers is still small, and they are very unevenly distributed over the globe. In Europe, where they are numerous, the position is quite different. The vast geographical literature of this continent is mostly due to individual workers who knew their country and had at their disposal copious facts and abundant statistical data of all sorts, and above all excellent topographical maps. But consider the basis of our knowledge of large parts of the southern continents and of Asia. We derive much of our information from the accounts of primary exploration, some of the best of it contributed by the great pioneers, the naturalist travellers of the nineteenth century. Since their day the mesh of the net has become closer ; expeditions have been better equipped ; scientific aims have become more definite ; route surveys have improved. Yet the fact remains that comparatively few expeditions engaged in primary exploration have yielded well-balanced explanatory accounts of all the elements which might be the subject of observation in the regions traversed. This defect doubtless will be attended to more often in the future. But the records of exploration having the character of traverses must nearly always be limited, since observations are usually confined to one season of the year.

I do not, however, propose to develop this aspect of the question ; for the suggestion which I have to offer applies rather to regions where

pioneer exploration is regarded as finished, and especially to the colonies and dependencies of the more advanced nations. I submit that these regions offer the most fruitful field for geographical research in the nearer future. As the chief reason for this belief I would mention the justifiable hope of the rapid extension of systematic surveys in such countries; and we are agreed, I think, that the basis of all sound geographical research is a reliable topographic map, supplemented if possible by the results of geological surveys.

Brigadier Jack, as President of this Section in South Africa, devoted his address to the need for extensive regular surveys and to the many practical advantages accruing from them; and the Sectional Committee last year asked the Council of the Association to point out to our Government that the lack of reliable surveys and maps in the British Colonies and Dependencies greatly delays scientific and material progress. I am therefore only reiterating the firm conviction of geographers when I say that scientific knowledge of the continents can scarcely begin to make rapid progress until they have been adequately mapped. In the regions where this aim has already been achieved, as in India and in parts of Indonesia as well as in some of the African Colonies, I feel that geographers, given at least one year in well-chosen 'key' districts, could do a great deal to promote a real understanding of larger regions, especially in the field of human geography. We should, I think, use every means to make such investigation possible. But I have repeatedly asked myself whether there is no other way in which we can accelerate the process of gathering the type of information needed for the composition of geographical syntheses which may be at least fuller and better than those we now possess. And it has been borne in upon me that the right way lies in the direction of co-operative effort.

The idea of extensive collaboration in geographical research is by no means new. An obvious method which has been employed consists in the concentration upon a given region of work by specialists in each of the earth sciences, resulting in a series of individual monographs. But unless there be a concluding volume in which all the results are causally linked, the work is not geography. An outstanding example of this kind is the great investigation of Lake Balaton and vicinity undertaken by the Hungarian Geographical Society in 1891, and involving nearly a hundred contributors. Most of the voluminous work was published,[1] but unfortunately the geographical synthesis is still awaited. The same Society in 1905 organised a similar work upon the Alföld, but the war seriously interfered with this. The International Geographical Union, since its formation, has promoted co-operative research on various subjects the majority of which are of a physical character. Thus the creation of commissions to deal with these investigations marks the extension of an older and similar type of organisation well represented by the International Glacier Commission or by various national research bodies such as the late Sir John Murray's Bathymetrical Survey of Scottish Lochs or the Royal Geographical Society's Committee on

[1] *Resultate der Wissenschaftlichen Erforschung des Balatonsees*, Budapest, 1897 onwards.

English Rivers. It is, however, significant that two of the new International Commissions are devoted to aspects of human geography. Of these one deals with Over-population in its Geographical Bearings. It has not yet had time to develop its work fully. The other, on Types of Rural Habitation, has accumulated a vast amount of material contributed by many geographers and is likely to render great service to our science. Somewhat similar in aim is the separate co-ordinated study by a group of German geographers upon settlements in a large variety of regions throughout the world, and whose papers have recently appeared.[2] Perhaps the most striking instance of an organised geographical investigation designed to be of definite advantage in future national planning is that of the American Geographical Society relating to problems of pioneer settlement throughout the world. The firstfruits of this, which have already been published,[3] represent the results of regional studies by selected geographers and a synthesis by the organiser, Dr. Isaiah Bowman. Associated with this is the intensive work upon the Prairie Provinces of Canada, which occupied five years. Its results, now in course of publication [4] under the editorship of Prof. W. A. Mackintosh, represent the first large undertaking of co-operative scholarship in the Dominion. I understand that it is a most comprehensive work in which geographical factors have received due consideration, although the authors are exponents of other subjects.

I have mentioned these examples in order to indicate the extent to which we already depend upon the fruits of co-operative investigation. But it is clear that the collaborators in such projects have always been geographers or people whose life's work lies in some branch of science or learning that can be made to serve our purpose. But I now return to my original theme, the scanty nature of the data upon which our geographical generalisations so often rest, and the long period that must probably elapse before trained geographers duly equipped with maps can cover the immense field by personal investigation. Let us consider Africa as an example, with special attention to its inhabitants.

During the past decade or so an increasing interest has been taken in the future of the black race in Africa, and the literature bearing upon the relations between Europeans and Africans has already assumed considerable dimensions. But before arriving at a considered judgment regarding the future of the native it is evidently necessary to understand the native as he is, the life he leads and the beliefs he holds. These are matters proper to the study of anthropology; and in fact that science has dealt very fully with the African races and is prepared to answer most of the questions that are usually asked relating to the natives. Nevertheless, in 1926 I found it necessary to point out [5] that the geographical controls or

[2] F. Klute (Ed.), *Die ländliche Siedlungen in verschiedenen Klimazonen*, Breslau, 1933.

[3] 'Pioneer Settlement, Comparative Studies,' *Amer. Geog. Soc. Special Publication*, No. 14, New York, 1932. Isaiah Bowman, 'The Pioneer Fringe,' *ibid.*, No 13, New York, 1931.

[4] By Macmillan, Toronto.

[5] 'Africa as a Field for Geographical Research,' *The Geographical Teacher*, vol. xiii, pp. 462–467.

influences affecting the material life of these peoples usually receive far too little attention. Indeed the physical environment as a rule is quite inadequately treated in the anthropological literature of the continent. I was interested to find soon after this that my colleagues in this Section agreed with me both as to the gaps in our knowledge and as to the great importance of attempting to fill them. A Research Committee of the British Association was therefore appointed after the Oxford Meeting to investigate the state of knowledge of the Human Geography of Inter-Tropical Africa; and this Committee has been increasing its activities ever since. We set ourselves to state clearly the points upon which information was badly needed, and then proceeded to lay plans for tapping a body of knowledge which we believed to exist in Africa, but which hitherto had scarcely been tapped in the interests of geography. Scattered throughout this continent are many men and women who, with long residence in close contact with the Africans and personal experience of the environmental conditions year in year out, should be able, by answering specific questions, to provide the essential link between the land and the mode of life of the natives. We had in mind chiefly the District Officers of Colonial Governments, and missionaries. To them we sent our nineteen questions, most of which might be considered to apply to any of the regions envisaged. We included them in a pamphlet [6] that gave in addition a brief explanation of our aims and reprints of two model essays on the relation of African tribes to their environment, those of Père L. Martrou on the Fang and Mr. R. U. Sayce on the Basutos.

Human Geography of Northern Rhodesia.

The most comprehensive response received so far has come from Northern Rhodesia, where the late Governor was good enough to transmit our request to the District Officers of the Protectorate, with the result that we have at our disposal a series of thirty reports covering the whole territory save for two Districts, in area the equivalent of France with the Low Countries and Switzerland, and dealing with the life conditions of well over one million people.

The aggregate volume of the Northern Rhodesia reports is considerable, amounting to well over 200,000 words; some are quite brief, others are long and generally proportionately useful. I propose presently to state in summary form some of the results of a synthesis derived from their contents. Before doing so, however, I wish to express on behalf of the Committee our indebtedness to the authors [7] for the trouble they have taken in responding to our invitation.

[6] *The Human Geography of Inter-Tropical Africa: The Need for Investigation*, 1930 (reprinted 1931).

[7] The authors of reports, and the Districts, are as follows: A. W. Bonfield, Serenje; H. F. Cartmel-Robinson, Fort Jameson; C. A. R. Charnaud, Mazabuka; E. H. Cooke, Feira; T. S. L. Fox-Pitt, Kasempa; H. A. Green, Kalabo; D. B. Hall, Kalomo (plateau); S. S. Hillier, Luwingu; G. Howe, Mporokoso; R. S. Hudson, Balovale; G. Hughes-Chamberlain, Mwinilunga; R. O. Ingram, Sesheke; E. K. Jordan, Isoka; S. P. L. Lloyd, Kasama; F. B. Macrae, Livingstone, Kalomo (valley) and Mumbwa; E. Munday, Chinsali; C. P.

There is special ground for satisfaction that the first of the British territories to make such full response is Northern Rhodesia, on account of the recent appearance of an important study of sociological and economic character which deals with almost the same region. This is the report of an inquiry into the impact of the copper mines of Central Africa upon Bantu society, and the work of missions, made by the Department of Social and Industrial Research of the International Missionary Council.[8] It is to be noted that the material now in our hands is almost wholly supplementary to the content of this book. Yet I venture to think that we are in a position to compile from our reports an account which will facilitate the full appreciation of the vital problems dealt with by Mr. Merle Davis and his colleagues.

It is a matter for regret, on the other hand, that we possess insufficient material from which to construct an adequate account of the physical geography of this region. The map is a compilation, with no real representation of relief, for stringent financial resources have hitherto prevented the undertaking of regular surveys. The presence of abundant reserves of copper in the central area has led, I learn, to much geological survey in recent years ; but, so far, few results have been published. There are no satisfactory general treatises either upon the soils or upon the natural vegetation. In regard to the climate alone are satisfactory data available ; for the Protectorate has some fifty rainfall stations established at least fifteen years and many with shorter records, while observations of temperatures are annually reported from some fifty stations.

Thus, with the exception noted, the physical setting, in which human existence is now so minutely described, still remains somewhat obscure. It is fortunate, however, for our purpose that over vast stretches of Rhodesia there is relatively little variety of natural landscape or of the causes which underlie it ; indeed, this is almost certainly true of the greater part of Central Africa. For this reason we are perhaps entitled to make the fullest use of accurate knowledge established in valuable surveys recently made across the northern border in the Katanga and now in course of publication by the Comité Spécial du Katanga. From the admirable sheets of this atlas [9] and the published writings of its creators we may gain real insight into the interrelations of structure, relief, soil, and vegetation cover which must be closely analogous to those prevailing in the Protectorate.

From our District reports we can glean much sporadic information upon each of these physical elements, and there are two types of statement which are real contributions to the physical geography of Rhodesia. The first supplements the climatic statistics by describing the local

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Oldfield, Abercorn ; M. B. J. Otter, Kawambwa ; F. R. G. Phillips, Fort Rosebery ; E. H. L. Poole, Lundazi and Petauke ; C. G. Stevens, Mkushi ; G. R. R. Stevens, Mankoya ; G. Stokes, Mpika ; H. A. Sylvester, Namwala ; P. D. Thomas, Senanga ; E. F. G. Thomson, Chiengi and Lusaka ; J. Moffat Thomson, Broken Hill ; J. F. Warrington, Mongu.

[8] J. Merle Davis, *Modern Industry and the African*, Macmillan & Co., 1933.

[9] H. Droogmans, M. Robert et G. Maury, *Atlas du Katanga*, Publication du Comité Spécial du Katanga, Bruxelles, 1928 onwards.

weather sequence throughout the year ; and the second concerns the regimen of rivers. I would draw particular attention to this matter, so important for the population ; we have received a statement from every District as to the permanence of streams and their flood character.

Physical Environment.

In order to have space for matter that is now available for the first time, I will describe the physical background in barest outline, mentioning only such facts as are important to the understanding of the human geography.

The fundamental crystalline skeleton of Africa appears here in two broad zones extending respectively from S.W. to N.E., occupying the south-eastern belt, and S.E. to N.W., extending over into the Katanga. The structure of this latter zone is complicated by the presence of a geosyncline of ancient continental sediments, including dolomitic limestones, that were folded by thrusts from the S.W. Their outcrops, therefore, lie along an arc concave in this direction. Associated with these folds and with certain igneous intrusions is the mineralisation of the zone, by lead and zinc in Broken Hill and by copper and other ores farther north. The south-eastern zone is seamed by a structural depression in which sediments of ‘ Karoo ’ age are preserved, said to contain coal as well as nitrates sporadically quarried by the natives for gunpowder. The Luapula basin in the north is largely underlain by Palæozoic sediments, but with granite intrusions, while throughout the drainage area of the upper Zambezi the ancient rocks are almost completely masked by the Kalahari sands.

The relief of Northern Rhodesia, like that of most of the Central African highlands, is monotonous. Planation over long periods accounts for this ; and consequently the hill ranges and inselbergs which form the chief accidents on a plateau standing mostly between 1,000 and 1,500 m. are chiefly residuals of stronger rock, while the more extensive elevations above this height, notably those dividing the Bangweolo ‘ saucer ’ from Tanganyika and from the Luangwa valley, will probably be explained by warping. The entire plateau seems to bear traces of indeterminate drainage with numerous evidences of river capture on all scales and of varied date. By far the most pronounced relief features are the margins of the south-eastern structural furrow drained convergently by the Luangwa and the Zambezi below the Batoka gorge. This, both on account of the height of the escarpments—generally more than 400 metres—which are to be regarded as erosional fault-scarps, as well as because of their extreme dissection by the regressive erosion of tributaries which are rapidly notching the plateau rims on both sides.

Time does not permit me to deal statistically with the climate, which is, of course, of inter-tropical type with markedly seasonal rainfall. In Rhodesia three seasons are recognised and named by the natives, the limiting dates varying with the locality : the cool season from March, April or May to July or August ; the hot, dry season from July or August to October or November ; and the rainy season lasting from these months to March or April. But in some districts, where there is a temporary break in the rains of from one to three weeks in December to January, a

lesser (first) and greater (second) rainy season are recognised. Moreover, in Barotseland a fourth has to be added, named *Munda*—the floods—for there the regimen of the Zambezi and tributaries is of prime importance.

There is thus a dry period of at least six months during which the temperature is first dropping to its minimum in July and then rapidly rising to its maximum in October or November. The rains then spread southward and eastward, the belt of maximum precipitation being in the north-west in November, and in the east around Lake Bangweolo in December. In January rain is more evenly distributed ; in February the maximum is again in the east, from which it gradually withdraws northward again. The total rainfall is over 50 in. near the Congo frontier, and decreases eastward to 35 in. on the Nyasaland border and southward to under 30 in. in the Zambezi valley.

The annual rhythm of vegetation, of animal life, and the seasonal activities of the population are matters upon which we have received much information, especially on the latter. These phenomena can now be closely related to the temperature and rainfall factors and the flooding of the rivers and variation of swamps and lakes.

In the absence of real knowledge of Rhodesian soils we may legitimately have recourse to the Belgian pedological work in Katanga, where, however, the rainfall is heavier. Owing to the very great extent of surfaces of peneplane type, it is most probable that the Rhodesian soils as a whole are residual and old, deficient in soluble salts and more or less lateritic. Moreover, deforestation over large tracts has proceeded for long ; and the removal of this natural protective cover results in the lowering of the water table during the dry season, and the loss of fertility, especially by the removal of humus, a contributory factor in this being the widespread annual grass fires. It may be regarded therefore as most likely that prevailing plateau soils are poor. Their vegetation is savanna, or what Shantz has classified as dry woodland, in which the trees are mostly deciduous and where their stature and their density varies with available water. They are, of course, associated with grass which is renewed each rainy season, and which, like the trees, varies with the rainfall.

Throughout the peneplanes are numerous shallow hollows known as *dambos*, filled by wash from the slopes, sandy and lateritic round their margins, clayey and marshy in their centres. Their soil is infertile and grass predominates in their vegetation.

By far the most attractive soils are those of the alluvial areas. In the maps of the Katanga these are distinguished according to age—young, adult and old ; and the District data from Northern Rhodesia would seem amply to justify this classification as one that is important in the human geography. But of course it is impossible to do more than guess the distribution of such types in any locality. The first class are annually inundated and renewed ; the second, which may occasionally be flooded, are typically dotted over with termite hills. The plant cover of both these types is herbaceous, and their edges would seem to form the sites of the great majority of native villages in the Protectorate, for such places are close to good soil, to water, and to trees, the three main desiderata of the Rhodesian cultivator. The old alluvium, on the other

hand, has lost much of its fertility through leaching, and possibly has become partly lateritic. It seems to be covered by somewhat xerophytic bush wood. The very porous soils developed upon the thick Kalahari sands of Barotseland would seem to be fairly good so long as the tree cover is maintained, with roots reaching the ground water, but to suffer rapid degradation when this is cut down.

Depredations by Man.

The inquiry has elicited certain facts about the modification of the natural vegetation by the natives. The great majority of the people live upon their crops, and most of these are raised in partial clearings of the savanna. The natives are truly men of the trees, apart from which they cannot live. The essential feature of their system of shifting agriculture, a system well known throughout the forests and savanna of inter-tropical lands, is the annual felling or pollarding of trees and the application to the soil of the ash derived from burning the wood on the site of their gardens. The name given to the practice in north-eastern Rhodesia is *chitemene* or *vitemene*, meaning ' those which have been cut.' The area of woodland cut for a garden of given size of course depends first upon the luxuriance of the trees, and secondly upon the nature of the practice—whether pollarding or felling. Throughout the drainage basins of the Kafue and upper Zambezi, as well as east of the Luangwa, it seems to be the habit to fell trees and to burn all branches, leaving the trunks to rot. This is also the method in part of Fort Rosebery and among the Awisa of Mpika. But to the north of the latter Districts trees are usually only pollarded, and this also seems to be the case in two central Districts, Mkushi and Serenje. The estimates of the ratio of timber area cut to area of garden vary between 4 : 1 and 10 : 1. The estimates of the period required for recovery of the woods are more numerous, but they are difficult to interpret in view of the inadequate accounts of the vegetation. In Mpika District the pollarded woods of the Awemba are left for about seven years, we are told, while the felled timber of the Awisa would require a generation to recover. Yet several District reports mention rest periods as short as four or five years ; in others these are between ten and twenty, and in Barotse thirty to thirty-five years.

The degree in which the savanna has degenerated under this system of agriculture depends largely upon the density of the population. Many writers point out that tracts of the natural vegetation still exist simply because the population is small—as, for instance, in Chinsali with three per square mile. But such figures are misleading, for the actual densities on land desirable from soil and water qualities are very much greater. Moreover, the native cuts wood for many purposes besides that of manuring his garden. He needs timber for a new hut every few years, for heavy garden fences, and for canoes. He fells trees to obtain honey, he strips trees of their bark. ' Bark,' writes the author of the report on Mongu,[10] ' comes more frequently into daily life than anything else ; every piece of rope used by natives and most of that used by Europeans is made of it,

[10] J. F. Warrington.

consumption is enormous and must be responsible for the destruction of thousands of trees and saplings every year.' Finally, there is the damage to seedlings and young trees caused by the annual grass fires which sweep the territory. These are started for various reasons. Fire may be allowed unintentionally to spread from the garden burning. Hunters use fire for two purposes: first, to promote rapid growth of young grass to attract game, and, secondly, in the case of organised hunts, to drive the animals in required directions. Stock-keepers also start fires to accelerate the appearance of fresh pasture, and, furthermore, long grass is disliked near villages for various reasons.

Migrations.

While no information was asked for regarding the physical or other characteristics of the inhabitants of Northern Rhodesia, yet a considerable amount of data of this kind has been received, and it will be placed at the disposal of the anthropologists. Nevertheless it is pertinent here to mention some of the geographical effects upon the migrations into and within the territory as revealed by tribal tradition and reported in the present documents. Most of the migrations referred to have taken place within the last two centuries, and the dominant direction appears to have been south-easterly from the southern part of the Congo basin. Thus the way seems to have been easy for tribes from the Congo-Zambezi watershed, either south-eastward through the upper Zambezi area or southward, over the peneplane drained by the Kafue, as far as the escarpment. The north-eastern plateau also seems to have been peopled by the present Bantu tribes chiefly from this same Katanga region of Congo, but here approach had to be either to north or to south of the Bangweolo swamps. The Awemba, who are now dominant in the centre, took the northern route, but have pressed south across the Chambezi, driving a wedge in the Awisa folk. Other tribes like the Lungu and Mambwe have penetrated south-westward from east of Lake Tanganyika. The most notable invasion from the south is that of the Makololo from Basutoland in the mid-nineteenth century to the country of the Aluyi, whom they conquered; their men were later massacred, yet Sikololo in a modified form remains the language of the region.

British rule has, of course, gradually brought these mass movements to an end; but there is one outstanding exception in the Barotse plateau, where there has been a steady infiltration of people from Angola from 1917 onwards, which represents a resuscitation of the older south-eastward drift. These immigrants, known collectively as the Mawiko or 'People of the West,' and now numbering 100,000 or more, have left Portuguese territory when discontented with its administration, and they have now penetrated Barotse Province to a depth of nearly two hundred miles.

A striking feature of human geography throughout Central Africa is the relegation of the weaker or more primitive peoples to the least desirable areas. In Northern Rhodesia these areas were the swamps of the plateau, and the hot lowlands of the Luangwa and the Zambezi below the Falls. In the former we find the backward Batwa or marsh folk, whose culture, however, has greatly advanced in recent years; in the Luangwa, the Senga

and others, who appear to have been forced thither by the Awemba or others from the west and the Ngoni raiders, of Zulu stock, from the east; while the low Zambezi valley is peopled by numerous debilitated tribal fragments.

External Influences.

The effect of European influence upon the economic and social structure of native society in Northern Rhodesia has recently been very thoroughly dealt with by Mr. Merle Davis in the work already referred to. It is, of course, not a geographical work, though geographical factors are recognised by the author. I have therefore attempted to make an estimate, based upon our District reports, of the nature and degree of external influence upon the material life of the natives. These influences differ widely in date and in potency. The acquisition of the chief cultivated plants and domestic animals reaches far back, and I do not propose to deal with this. Direct contact with the earlier Portuguese traders has been of little account, save possibly in the Feira District, but in the west their indirect influence has been considerable in view of the migration of tribes whose ancestors had been in touch with the Portuguese on the Atlantic seaboard. The use of manioc [11] bears witness to this, and the square or oblong type of house which to-day prevails in the two north-western districts probably derives ultimately from this source. In Balovale it replaced a beehive grass hut, and its superiority over the circular pole and thatch hut of the other Rhodesian areas is being recognised, as is the skill of its builders, who are often paid to build houses for neighbouring tribes. Since 1917, the new wave of immigrants from Angola has led to the spread of this house type throughout the upper Zambezi basin.

About the southern end of Lake Tanganyika there are evidences of various effects of the incursions of Arab slave raiders. Here again a square house is found mingled with the circular huts (Abercorn), while the small groups of Swahili people have groves of date palms and other cultivated fruit trees.

But these aspects are all insignificant in comparison with the potent influences due to the British rule and partial settlement by European farmers, the rapid exploitation of minerals in the Belgian Katanga and the Ndola and Broken Hill Districts of the Protectorate; while the establishment of missions throughout Rhodesia has had widespread material as well as moral effect. As indexes of the outward evidence of this permeation, which really amounts almost to revolution, I select data of three types: first, the distribution of houses built on the European pattern; secondly, the continuance or otherwise of the old-established native iron industry; thirdly, the direction and volume of movement of native labour to work for Europeans.

Houses built on the European model, either of wood or of sun-dried brick, are most numerous along the southern half of the railway; in Kalomo they are estimated at 10 per cent. Here also native iron-working is either not mentioned or is stated to have died out, or else the smiths have turned their attention from axes, hoes and spears to the repairing of ploughs and

[11] *Cf.* Fig. 3.

bicycles. These latter, which are rapidly multiplying, are a good index of prosperity, since their price is £5, and the possession of cycles gives special inducement to the people to keep the inter-village paths clear and encourages the habit of paying visits at a distance, the native's chief recreation even when he had to walk. This southern railway belt is, of

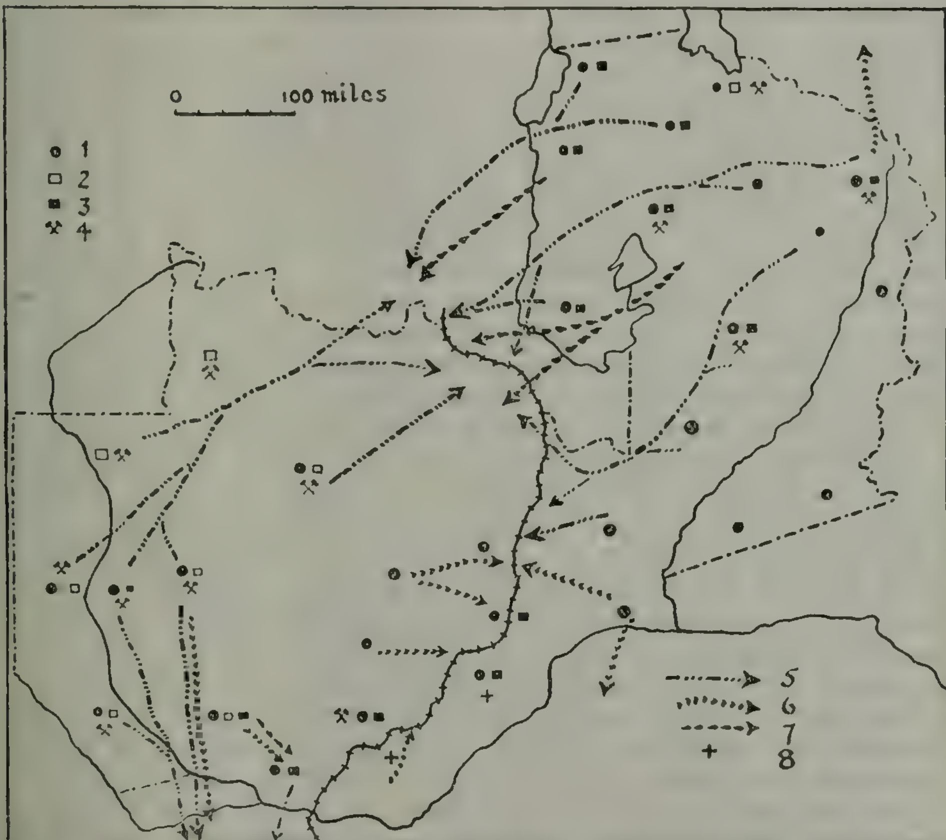

Fig. 1.—Cartogram of Northern Rhodesia to illustrate effects of External Influences.

(1) Rhodesian circular house; (2) Rectangular house of Bantu or Swahili origin; (3) Rectangular house on European model; (4) Native iron industry reported as still in operation; (5) Annual migration to European mines; (6) to other European employment; (7) to market produce; (8) Surplus produce sold locally.

course, the centre of European population, the effect of which is seen in the nature of money-earning employment. The poll tax of from 7*s*. 6*d*. to 12*s*. 6*d*., according to the region, is in Rhodesia the initial cause of the widespread annual migration of the younger men, but the desire for change and excitement and for luxuries increasingly influences it. Throughout most of the country natives have to travel far to earn money. But here in the south employment on farms, on the railway or in domestic service may be had at a distance usually much under one hundred miles. Moreover, surplus crops or stock may be sold for local use or for transport

by rail to the northern mines. Thus the annual movement in the south is for the most part convergent upon the railway strip for service or for trade ; from Feira some agricultural labour moves to Southern Rhodesia, and such men as prefer the mines may go by train either north or south.

Over the great north-eastern region European settlers are very few, and in East Luangwa they are concentrated about Fort Jameson. European influence, therefore, is either spread by the Administration, the missions, of which there are nearly forty, or by the migrating natives themselves. Copies of European houses occur in significant proportions throughout the Luapula drainage area, as well as in Isoka District. Only four of the thirteen Districts report native iron industries, the rest relying mainly on imported implements. The annual movement to the labour market is directed almost everywhere westward to the mines of Broken Hill, Ndola and the Katanga, the only important exodus for farm work being from Isoka to the coffee plantations of Mbezi in Tanganyika Territory. The distance travelled by the natives going to the mines frequently amounts to four hundred miles, and the average periods of absence from these northern districts are given as from six to nine months. The consequences of these long absences of the able-bodied men, whether accompanied by their wives or not, are fully discussed by Mr. Davis [12] ; I will mention only one result—the serious reduction of land in crops and the consequent increase of famine risk. From the Mweru Luapula Province there is a further movement into and across the Katanga. This marks the export of the surplus produce of the Province, consisting of dried fish and manioc meal for sale at the mines. Natives may make three or four such journeys a year, but some of this commerce is now in the hands of European traders, mostly Greeks and Italians. These also buy skins, notably those of the otters killed around Lake Bangweolo.

The western plateau, drained by the Zambezi, lies off all main routes. Moreover, the greater part of it is Barotseland, where limited self-government exists and missions are fewer than elsewhere. Consequently the region has less contact with the white man. European houses are mentioned only in Mongu (probably mission influence) ; and all the Districts either mine their own iron or at least manufacture many of their implements. Yet the whole basin sends its quota annually to the mines when labour is in demand there. From the southern half of the country the majority probably go to the Wankie or other Southern Rhodesian fields, and Mankoya also sends agricultural labour southwards. But from the northern districts natives walk, up to four hundred miles, to the copper belt.

Such are some of the regional effects of European contacts. But I must not omit to mention one which applies equally everywhere. Before British rule the Rhodesian natives lived dangerously. Because of inter-tribal wars and the risk of attack by slave raiders the people lived in large villages surrounded by stockades. With the new security their groups have been steadily growing smaller and tending to approach the natural unit which is the family, albeit a larger unit than that to which we apply the name. Government, however, has imposed its veto upon further

[12] *Op. cit.*

subdivision. Therefore it may be stated in general that the population is everywhere contained in villages varying in size according to local geographical conditions.

Population Density.

I have had to spend much time in studying the distribution of native population, since the responses to the Committee's request for information under this head varied greatly in value. The average density for the whole Protectorate is a little over four per square mile. The official figures of average density by Sub-Districts in 1931, however, at once draw attention to the uneven distribution of the people. Thus, two Districts in Barotse Province, Kalabo and Mongu, have densities of 11·6 and 16·3 respectively; Chienji on Lake Mweru has 13, while Fort Jameson has 20·8. On the other hand, in a belt from the Katanga border southward to Sesheke the District densities vary from 1·3 to 2·5, while in the railway belt to the east of this, figures are between 3 and 4. A cartogram made from these data, however, gives but a crude representation. In the first place, wherever there is a nucleus of European farmers the natives of the vicinity have been or are being moved into reserves, thus greatly increasing their density per square mile in these Districts. But it is the examination of life conditions which brings realisation of the real distribution. We have seen that agricultural village sites must of necessity be close to water, to reasonably good soil, and to trees. In the central District of Mkushi the actual distribution, almost entirely along the river valleys, was shown on a map by Mr. C. G. Stevens, from which I calculate densities of from 50 to 60 per square mile instead of 2·77 for the District, the interfluves apparently being inhabited. The evidence is insufficient and the map too vague to allow of such refinement being made for the whole territory, but I have had no great difficulty in plotting approximately the more outstanding variations in density. The following are some of the more interesting results of the operation.

The type of locality which carries the greatest population is that which provides a means of livelihood apart from agriculture; and fishing is by far the most usual supplement of this kind. Indeed it becomes the dominant occupation around Lake Bangweolo, where the islands have about 80 persons per square mile, and many shore areas must be nearly as densely peopled. Similarly, high densities occur along the shore of Lake Mweru and the banks of the lower Luapula. Such areas of good fishing which are also excellent land for producing manioc have received access of population in recent years on account of the encouragement to market fish and meal in the mining areas to the west.

Fishing, again, is the cause of the most concentrated population on the River Kafue below Namwala and round several small lakes in Kalabo. Here indeed, near the western border, the appearance of ground water from the sands seems always to draw people in an otherwise dry region. The great alluvial plains of the Barotse, the Kafue Flats, and the reserves east of the Luangwa are all relatively populous districts in which cattle are held by cultivators. Apart from the areas mentioned and a few others less notable, the population densities, calculated on the assumption

of stream-bank arrangement, would seem to vary from, say, 5 to 10 per square mile in Districts of small population to 40 to 50 in the more populous.

Tsetse Fly.

No element of the human environment is more important than the distribution of the tsetse flies (*Glossina*). *G. palpalis*, the carrier of sleeping sickness, appears happily to be either absent or innocuous over nearly all the country, the only districts where the disease has been

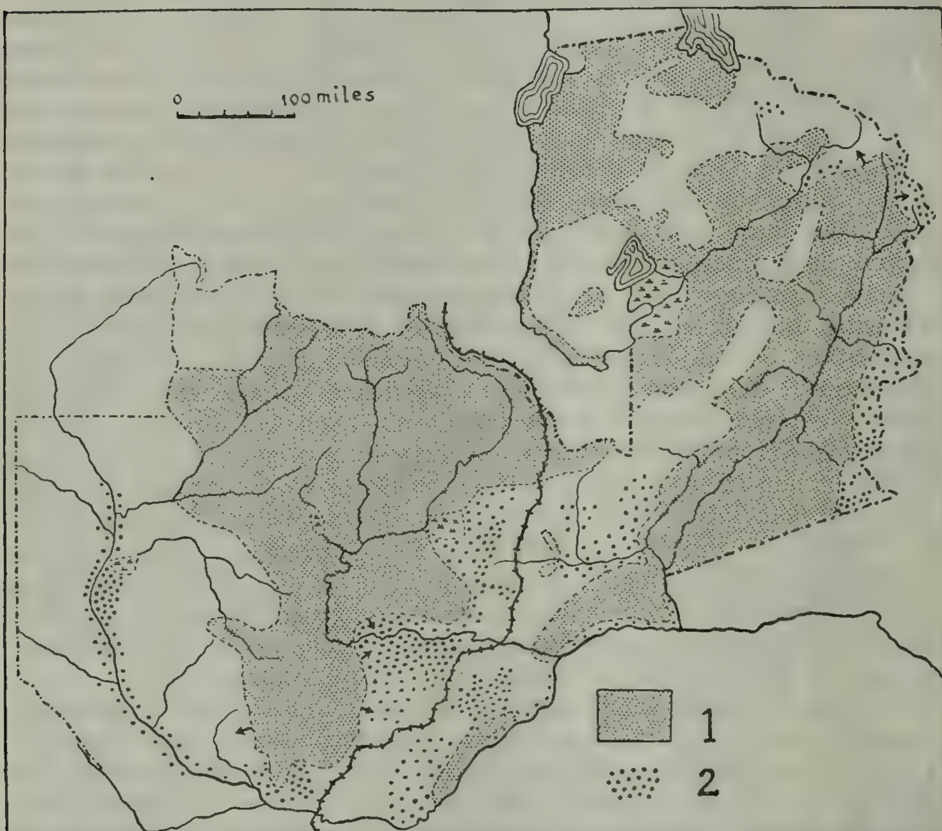

Fig. 2.—Sketch-map of Northern Rhodesia, showing Distribution of (1) Tsetse Fly and (2) Native-owned Cattle.

reported in recent years being the Luapula and Luangwa valleys, the shore of Lake Tanganyika, and a small part of the upper Kafue valley. But with the bearers of *Nagana* it is quite otherwise. The presence of these flies is a menace to cattle owners, European and native, and unfortunately they infest the greater part of the territory. Their distribution, as plotted from the reports and certain local maps, reveals three large tracts that are free of fly. The first includes the greater part of Barotseland. East of this lies a broad fly belt ; within this the flies seem to be spreading, and at the southern end the belt is extending both eastward and westward toward the native and European cattle land of the lower Kafue and the

railway zone. This latter, with its greater amount of cultivated land, is still free of fly to the edge of the great escarpment, and the same is generally true of its continuation north-eastward along the divide between the Chambezi and Luangwa; Broken Hill and Mkushi even report a reduction in fly. The Luangwa fly belt shuts off the clear area of the Nyasaland border, and at the head of the valley the pest is encroaching on the plateau land. The tsetse distribution is more patchy in the northern areas. Generally speaking, the higher lands are the freer. In Fort Rosebery the fly is local, and Kasama records a reduction; but evidently there are few areas which can safely be reached by cattle.

The map indicates clearly the prevalence of tsetse in the hot lowlands, but the controlling factor on the plateaus, which is doubtless the character of the vegetation, cannot be examined until a survey of that element has been made. The nature of the wild fauna is a contributory factor; and while the reports contain useful information regarding the wild animals which are hunted or cause depredations to crops, it is insufficient to allow of any important deduction.

Cattle.

While cattle are restricted to the areas free of fly, they are by no means evenly distributed throughout these parts. Nor are they of equal significance in the life of their owners, chiefly on account of varying tribal tradition in regard to cattle, but also from the incidence of European influence. In Barotse it is the Maroze chiefs and indunas who are the chief cattle owners, and the herds vary according to the available pasture, being greatest on the Zambezi plain (in Mongu *c.* 50,000 head) and decreasing north and south. Cattle in general are regarded merely as wealth, chiefly in relation to the marriage security, sometimes as a source of meat and of hides, more rarely of milk. But in contact with Europeans and a market, the tribesman tends to devote his animals to work, notably with the acquisition of the plough in the alluvial plains, of two-wheeled carts on suitable ground and of sledges elsewhere. It is chiefly in the vicinity of the railway that the natives are following European guidance in the matter of breeding and of dipping. Elsewhere the herds receive little attention, and consequently the stock is poor. Furthermore, the Barotse cattle were stricken with pleuro-pneumonia in 1915 and their numbers reduced by perhaps 50 per cent. In the central Districts, on the other hand, stock is increasing, owing to the natives' contact with Europeans. This feature is most pronounced in Mazabuka, where the Tonga and Lundwi have over 108,000 head, and as these have recently been driven into the reserves, there is a risk of overstocking. This reacts not merely directly on the animals, but indirectly and permanently upon the land, which is much more serious. It results in rapid erosion of the soil wherever there are slopes.

Cattle, of small size and few in number, are kept in the Zambezi lowland along the river banks and partly shut off from the plateau by a fly belt. Similarly a few animals only remain in the hot Luano valley of Mkushi, though formerly the herds there were sufficient to attract the Ngoni raiders from the east. The Ngoni and other tribes of the Nyasaland

border form the remaining native group which keeps large numbers of cattle; for the tribes of the northern plateau, in spite of considerable available land, are not pastoralists to any extent, the chief exception being the Isoka District with 7,000, where, however, tsetse, extending up from the head of the Luangwa valley, has been causing destruction.

Small stock in Northern Rhodesia are widely spread: they are in almost every village and receive very little attention. Goats are a universal possession, far outnumbering cattle in most parts, and the same may be said of poultry; sheep are more local in distribution, and pigs, which become crossed with the wild variety, seem to have an uneven distribution.

Transhumance is practised by the cattle owners of the Barotse Plain and the Kafue Flats, in each case in response to the flooding of the alluvial belt. The Maroze possess two sets of villages, on the plain and in the savanna respectively. They occupy the former from May to January, cultivating their maize and grazing their cattle; then, when the Zambezi rises in February, they move to their woodland villages, where the cattle manure their manioc and millet land. The inundated villages have, of course, to be repaired regularly before reoccupation. The Baila of the Kafue, on the other hand, live in large permanent villages, above the floods and far from the river, where they grow maize. The river is at its highest in March and, when the floods have receded in June, the migration to the flats takes place, grass being burned for hunting and grazing; temporary villages are occupied, where fishing can also be had. The Baila are exceptional in the variety of their diet of maize, fish, milk, and game meat.

Food Staples.

The distributions of four of the leading food crops of Africa meet and overlap in Northern Rhodesia; the three cereals, comprising the great millet—sorghum, the lesser millets of which eleusine is the most important, and maize. These, with manioc (cassava), form the food staples of the native population. Allowing for some uncertainty as to the identity of the millets mentioned by the authors of reports, it has been possible to plot the crop distribution with general accuracy. It is thus evident that the small millets, especially eleusine, prevail in the north-eastern plateau while sorghum is more cultivated in the central Districts. This crop, however, has yielded the first place over most of its area to maize, most probably introduced from the south and certainly increasing where the contact with European farming is close. The most outstanding fact elicited is the penetration of the territory by manioc as a staple crop. The lower Congo region is generally held to have been the centre of dispersion of this American plant, and it will be interesting to learn whether its area is now unbroken to the Rhodesian border. It is clear that manioc is still being carried south-eastward by the Angolan immigrants in Barotse, and, for reasons to be mentioned, its cultivation is being encouraged elsewhere by the Administration. Its appearance along the railway belt and its dominance in Lusaka are perhaps due to this. But manioc is also the staple along the Luapula valley and thence eastward to Lake Tanganyika. Where the small millet appears as secondary crop

it is often grown solely for the beer that is brewed from it. Such 'beer crops' are those secondary to manioc in Chiengi and Fort Rosebery, and that of Kasempa, subsidiary to sorghum.

To understand the geographical significance of these crops it is necessary to examine the manner of their cultivation. The preparations for millet-growing appear to vary but little. The lopping of trees and heaping of

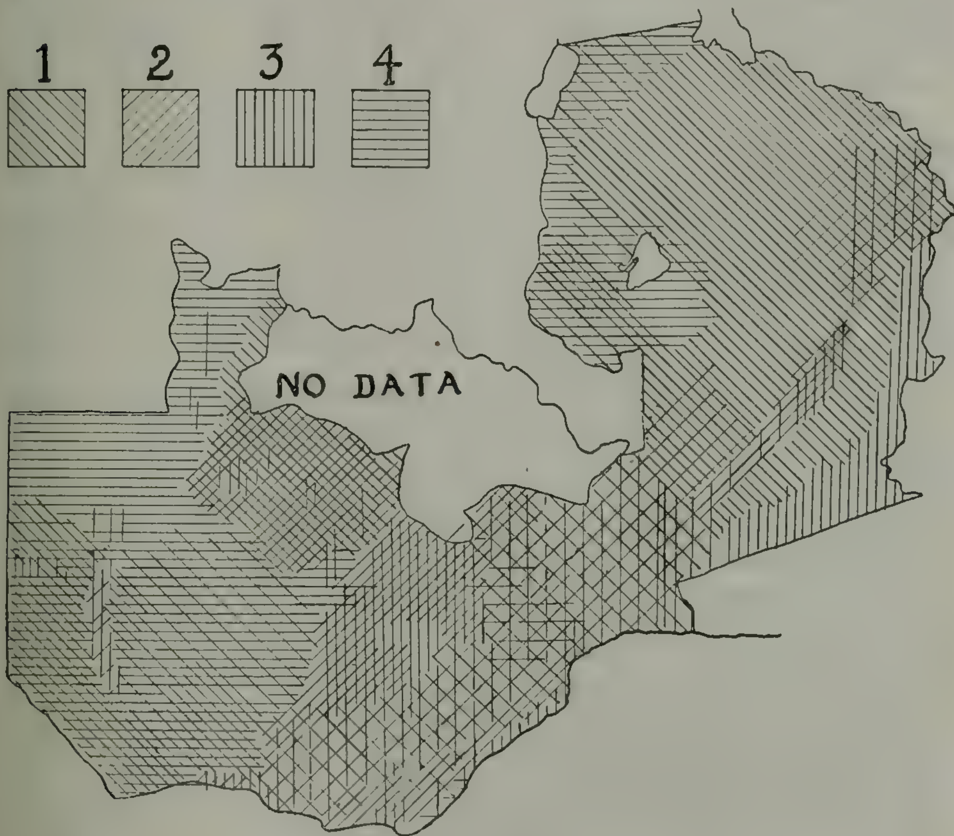

Fig. 3.—Cartogram of Northern Rhodesia, showing Distribution of leading Food Staples.

(1) Small Millet, generally Eleusine; (2) Sorghum; (3) Maize; (4) Manioc (Cassava). For sake of visibility, rulings have been drawn over European as well as Native areas.

the branches on the cleared garden site are completed by the end of the dry season and the burning takes place, usually on the chief's signal, just before the first rains; if this is done too early there is a risk of the precious ash blowing away. The seeds are then planted in the ash-covered soil during the early rains; and the millet crop is directly dependent upon rainfall for its water and upon wood ash for its nourishment. Hence it is the only cereal which flourishes on poor, lateritic soils. It is therefore the characteristic grain of the savanna away from the alluvial strips of rivers, which are devoted in general to sorghum or maize. The same conditions govern the cultivation of ground nuts, which are generally

associated with the smaller millets. In many Districts the main part of the garden is devoted to millet for only one year, a new garden being prepared for the staple crop each year, and the old garden used for mixed subsidiary ' relish ' crops. The number of successive years in which a garden grows millet must, of course, depend upon soil fertility, and as we have little information about the plateau soils, no deduction can be drawn from the facts recorded. But three years appears to be the maximum, save for special reasons. Thus the Amambwe of the north-east, who are industrious hoe cultivators, have a four-year rotation system, consisting in millet, fallow, a leguminous crop or maize, and again millet, by which they use the same garden for eight years or more. Again, the Maroze cattle owners of the upper Zambezi systematically manure the ground by moving their kraals at intervals, when the cattle are in the savanna during the Zambezi flood season. These, however, are exceptions, and it is abundantly clear that dependence upon a millet crop results in the maximum destruction of timber, with the attendant impoverishment of the soil. Moreover, this reliance upon the *chitemene* system accounts for the temporary character of settlements, which is characteristic of all but a few areas of the Protectorate.

Gardens must repeatedly be moved to avoid carrying wood for long distances. Soon the gardens are found to be inconveniently far from the village, and so this is moved. There are many social and economic consequences of such an unstable form of existence. Soil exhaustion is by no means the only cause of the movement of villages ; among the others are various superstitions and the insanitary condition of huts. But it is only for agricultural reasons that the displacement amounts to several miles. At the same time it must be remembered that the people usually return to the original site after a lapse of time sufficient for the recovery of the woodland ; they are deeply attached to their own special piece of country. Each District Officer was asked to state the average period during which villages remain in one site, and in general the life of the savanna village appears to be from three to four years. Where it is shorter there is probably exceptional poverty either in soil or in trees, and, conversely, longer periods are to be accounted for by abnormally good conditions.

The small millets are grown nearly everywhere to some extent for the purpose of brewing beer, and in Districts where they also form the staple food there is grave risk of the native's improvidence leading to famine during the months, generally February to April, before the new crop is ready, as in Luwingu, north of Lake Bangweolo, for example, where about one-half of the eleusine is devoted to beer.

Manioc as a Rhodesian crop offers several contrasts to millet. In the first place the natives, after planting the shoots on the mounds they have prepared, must wait for at least one year before the tubers mature ; and this period may be eighteen months, as in Chienji, two years, as in Mankoya, or even three, as in Mongu. This implies a greater amount of foresight than is the case with other crops and also more stability of the population, for since two crops may be taken successively from the same patch, a garden will last five or six years (e.g. Mwinilunga). Secondly, the cultivator does not have to spend time in scaring birds from his field or

in constructing heavy fences round it to keep off graminivorous animals, as he has to do if he grows cereals ; nor does he risk loss from plagues of locusts. On the other hand, the manioc suffers much in every District from depredations of bush pigs and from elephants where these are numerous. Thirdly, this plant is less susceptible than the cereals to rainfall deficiency. For all these reasons the inhabitants of manioc Districts rarely suffer from hunger—indeed there are several which have a regular export of cassava meal ; ' meal in Mankoya is almost a currency.' The Government is obviously fully justified in its efforts to induce extended cultivation of this valuable and reliable plant.

The other two common staples are sorghum and maize. Both are more characteristic of relatively treeless land, and the former is the more resistant to drought. At their best they are the crops of the open alluvial plains, and we find them characteristically in the river bank gardens of the Zambezi and Luangwa and many of their tributaries, where two crops are often taken—especially of maize—the first from the wet silt of the receding river flood, and the second from the summer rains. We also find them on the older alluvium abounding in termite hills, which form the very best soil when levelled. But these cereals are by no means restricted to alluvial soils, as witness their wide distribution on the central plateau on both sides of the railway. Maize in outlying Districts is commonly eaten green, but here there is a market for surplus grain which may be sold for transport to the mines. Herein lies the importance of the freedom of this area from tsetse fly ; for the cultivator is also a cattle owner and he has readily taken to the plough.

Ploughing gives great advantage in maize cultivation, and some also in the case of sorghum. Moreover, the acquisition of carts enables the native to market his produce. Yet even from this central region it is interesting to note that in the Broken Hill District, sorghum and eleusine are both commoner than maize, which is disliked because harder to grind. Again, in the plateau section of Kalomo, while maize predominates in the east where ploughing prevails, this is not true of the fly belt to the west, for here ground must be hoed, and the hoe is the woman's tool. But the women cannot be induced to raise a surplus for export.

This account of the distribution of staple crops must suffice to illustrate the kind of contribution which co-operative inquiry has made to our knowledge of the native agriculture.

I have now given a fair sample of the kind of information which we have gained by this piece of co-operative research in human geography. There are many other matters that I have had to omit. For instance, the inquiries as to animal pests and to the amount and nature of hunting have led to replies which give a good general idea of the distribution of the principal mammalian fauna. Again, we have learned much of fishing in relation to the rise and fall of rivers ; we have data relating to the seasonal migrations in search of fish and various food relishes such as caterpillars. Most important of all is the whole subject of seasonal rhythm of occupation and its regional variations, a matter upon which the reports are of great service.

Conclusion.

I have devoted most of this address to Northern Rhodesia for four reasons: First, because it is now possible for the first time to give to this Section some idea of the real results of an inquiry set on foot within the Section. Secondly, because these results themselves represent new material contributed to the geographical synthesis of a region still very imperfectly known—material, moreover, which is really geographical in nature. It relates to specific localities and it records both the human actions in these and the explanations in so far as they are traceable to special environmental factors. My third reason lies in the importance that I attach to directing the attention of all interested in Africa to a close understanding of the conditions of the natives' material life, which, simple though it is, yet varies considerably throughout the continent. Finally, I have in mind the wider implications of the success of this investigation.

Our Committee hope that the other African territories will do for us what Northern Rhodesia has done, and answer our nineteen points, or such of these as are applicable, district by district. But I am looking beyond Africa to countries where many Europeans reside, people who may never have thought of geography as we regard it, but who might well be sufficiently interested in the land of their choice to be willing to take part in the kind of team work which I have outlined.

Take India as an example. In spite of voluminous official and other literature, we have still a great deal to learn of the geography of man in the sub-continent. Although the task of gathering the information there would be much more complex than in the case of Africa, there would be certain offsetting advantages. Among these are: the accuracy of the map of India, the existence of a great body of data created by the various scientific services, and a wonderful census organisation. In addition, there is the likelihood that men of science could be found on the spot who would be able to fill in the gaps in the picture of the physical environment. These might be asked to deal with the numerous connecting links which are not usually required for official departmental reports but are nevertheless essential to the geographer.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

THE FUTURE OF RAIL TRANSPORT

ADDRESS BY
H. M. HALLSWORTH, C.B.E.,
PRESIDENT OF THE SECTION.

One hundred years ago the 'calamity of railways,' as Sir James McAdam termed it, fell on the existing means of transport. Though the Stockton and Darlington Railway had been opened for traffic in September 1825, and the locomotive had been known since 1804, it was still doubtful whether locomotives could be used on lines with heavy gradients. It was the success of Stephenson's 'Rapid' and Hawthorn's 'Comet' on a section of the Newcastle and Carlisle railway in March 1835 which set the seal on their success, and led railway promoters to think no longer of horses and stationary engines as the tractive power on the new roads. Three years later locomotives were working the whole length of the line from Newcastle to Carlisle, and an era of rapid railway development began.

The effect of railway competition on the canal companies, the stage coaches, and the road carriers of that time is well known. At first slowly, yet in the end surely, and in spite of severe reductions in their tolls, the canals lost all but the slow and bulky traffic. The effect on the turn-pike roads was no less severe. Horse-drawn traffic, it is true, not only survived the early days of railways, but actually increased, though long-distance journeys by road, whether of passengers or goods, practically ceased. As Prof. Clapham says, 'Carts and cabs increased, but coaches and posting-horses decayed. Journeys behind horses multiplied; but long journeys behind horses stopped. . . . The tragedy was repeated on each trunk route as the sleepers and metals were laid along it. . . . The effect in every case was instantaneous and inevitable.'

To-day it is the railways whose established position is assailed. Competition by road has taken on a new form; coastwise traffic has increased; the reliability and efficiency of the internal combustion engine has opened up the air for a third competitor.

In view of these developments in transport, what is the future position of the railways likely to be? Are they to be displaced from their position as the chief mode of transport, to which the rest are supplementary, and to be relegated to a position of secondary importance in the transport system of the twentieth century? It is a question of far-reaching importance. I agree with Sir Josiah Stamp that of the country's domestic problems at the present time none presses more gravely on the nation than the position and future outlook of the railway system. The number of workpeople it employs, the amount of capital invested in it, the increasing difficulty of providing for and controlling the traffic on the roads, the vital importance of securing for the community the most

RAILWAY REVENUE. RECEIPTS OF THE FOUR GROUPED COMPANIES.

Year.	Passengers.		Mails and Parcels.		Merchandise.		Coal and Minerals.		Live Stock.		Miscel-laneous.	Total.	
	£m.	%	£m.	%	£m.	%	£m.	%	£m.	%	£m.	£m.	%
1913 . .	41·3	—	9·1	—	30·6	—	31·0	—	1·2	—	0·9	114·1	—
1923 . .	68·9	100	17·4	100	51·2	100	54·2	100	2·0	100	1·9	195·6	100
1924 . .	70·2	102	17·0	97	49·6	97	52·4	97	2·0	100	1·8	193·0	99
1925 . .	68·9	100	17·3	99	49·6	97	49·9	92	1·9	95	1·8	189·4	97
1926 . .	60·6	88	16·8	97	45·6	89	35·9	64	1·8	90	1·6	162·3	83
1927 . .	63·5	92	17·6	101	52·1	102	53·1	98	2·0	100	1·6	189·9	97
1928 . .	62·1	90	17·4	100	49·4	96	48·9	90	1·9	95	1·7	181·5	93
1929 . .	60·0	87	17·6	101	49·0	96	52·7	97	1·8	90	1·7	182·8	93
1930 . .	57·0	83	17·5	101	45·5	89	49·2	92	1·8	90	1·6	172·6	88
1931 . .	52·4	76	16·8	95	41·8	82	44·5	82	1·6	80	1·5	158·5	81
1932 . .	49·2	72	15·9	91	36·8	71	40·7	75	1·4	70	1·4	145·3	74
1933 . .	49·4	72	16·0	92	36·6	71	40·7	75	1·2	60	1·4	145·3	74

economic and efficient system of transport that our present means and knowledge permit, combine to make it one of the most pressing problems that we have to face. Nor is it a situation confronting this country alone. A similar position has arisen in practically every country in the world.

In view of these considerations, and quite apart from the fact that my own studies have mainly been in the subject of transport, I felt that I could not choose a subject more appropriate for a presidential address to this Section, and for a city so dependent on transport as Aberdeen than the future of rail transport.

If justification for my choice were needed, I think I could find it in the Presidential Address of my predecessor, Henry Sidgwick, when the British Association last met in Aberdeen forty-nine years ago. The subject of that Address was the 'Scope and Method of Economic Science,' and I venture to think that my own paper comes well within the field which he there mapped out for economic thought.

It will be well at the outset to examine briefly the position of the railways of this country in the post-war years. For this purpose some statistics are essential, though I will endeavour to reduce them to the minimum.

The table opposite gives the revenue earned by the four grouped railway companies and the percentage change for the chief of the post-war years. The corresponding figures for 1913 are given, though in comparing the later years with 1913 it is, of course, necessary to bear in mind the change which has taken place in the value of money.

The form of railway accounts was amended in 1928, and though the figures for 1927 have been recompiled on the new method, it has been possible only to make approximate adjustments for the earlier years. Nevertheless, if not pressed too far they may be used for comparative purposes.

Railway revenue has, it will be seen, fallen by no less than 26 per cent. since 1923, and the fall has been most marked since 1929. Owing to the general strike and the coal dispute, 1926 was, of course, an exceptional year. The fall has been more severe in the case of passenger traffic and merchandise than in that of coal and minerals, though the revenue from the carriage of live stock also shows a big decline. The revenue from mails, parcels, and goods by passenger train has been surprisingly well maintained.

Compared with pre-war years the expenditure of the railways shows a considerable increase, due in part to the increase in the cost of materials, but chiefly to the rise in the level of railway wages, which in 1932 were 117 per cent. higher than in 1914; or allowing for the rise in the cost of living, 51 per cent. above the pre-war level. But since 1924 the expenditure shows a considerable reduction, partly owing to the lower cost of materials, partly owing to the numerous economies effected by the companies in their mode of working since 1923, and partly, of course, due to diminished traffic.

The changes in expenditure and the net revenue of the companies, both from railways proper and from their ancillary undertakings, such as canals, hotels, and docks, are shown in the table on the next page.

EXPENDITURE, RECEIPTS, AND NET REVENUE OF THE FOUR GROUPED COMPANIES.

Year.	Railway Expenditure. £m.	%	Railway Receipts. £m.	%	Railway Net Revenue. £m.	%	Revenue from other Undertakings, including Joint Lines. £m.	%	Total Net Revenue. £m.	%
1913 .	72·0	—	114·1	—	42·1	—	3·1	—	45·2	—
1923 .	156·9	100	195·6	100	38·7	100	6·9	100	45·6	100
1924 .	157·7	101	193·0	99	35·3	91	6·0	87	41·3	91
1925 .	156·0	99	189·4	97	33·4	86	5·2	75	38·6	85
1926 .	145·2	93	162·3	83	17·1	44	3·5	51	20·6	45
1927 .	151·8	97	189·9	97	38·1	98	4·5	65	42·6	93
1928 .	145·2	92	181·5	93	36·3	94	4·7	68	41·0	90
1929 .	143·9	91	182·8	93	38·9	101	6·1	88	45·0	99
1930 .	139·5	89	172·6	88	33·1	86	4·6	67	37·7	83
1931 .	128·5	82	158·5	81	30·0	78	3·4	49	33·4	73
1932 .	121·4	77	145·3	74	24·0	62	2·5	36	26·4	58
1933 .	119·4	76	145·3	74	25·9	67	2·9	42	28·8	63

It will be seen that railway expenditure has been reduced almost in proportion to railway receipts. The net railway revenue of the four grouped railway companies has fallen to 67 per cent. of the amount in 1923, whilst the net revenue from all sources has fallen to 63 per cent. of the 1923 amount.

Similar declines in receipts and expenditure are to be observed in most of the European railways, as in those of the United States of America, as the table on p. 123 shows.

The railways selected have been chosen to show how the serious fall in receipts has affected countries with widely differing characteristics. It will be noticed that the fall in receipts on the British railways, serious as it is, is not so great as in most of the European countries; but it should be remembered that in Great Britain railway receipts had not, as in these countries, been rising fairly steadily up to 1929.

The effect of the changes in receipts and expenditure on British railways has been very marked. First in the numbers of staff employed. In 1921 the number of staff on the railways comprised by the four grouped companies, including the Railway Clearing House, was 735,870. This had fallen to 681,778 in 1923, to 642,137 in 1929, and to 615,592 in 1931.

The effect on railway dividends has, of course, been even more marked. In 1913 the net revenue earned by the companies within the groups represented 4·41 per cent. on all capital. The return was 4·40 per cent. in 1923, 3·96 per cent. in 1927, 4·17 per cent. in 1929, 3·48 per cent. in 1931, 2·30 per cent. in 1932, and 2·68 per cent. in 1933.

The stocks chiefly affected are, of course, the ordinary stocks. The average earnings on ordinary stocks were in 1913, 5·55 per cent.; in 1929, 3·27 per cent.; in 1931, 0·95 per cent.; in 1932, 0·57 per cent.; in 1933, 0·77 per cent.

The causes of this decline in railway traffic and railway revenue are not far to seek. They are industrial depression, the contraction of international trade, and the competition of roads, and to a lesser extent of coastwise and air transport.

In the case of passenger traffic it is probable that a relatively small part of the decrease is due to economic depression, and that the bulk of it is due to road competition, including that of the private motor-car. Thus if we compare 1929, a year of relatively good trade, with 1923, in which trade was definitely not as good, we find a marked diminution both in the total number of ordinary passengers and in the total receipts from them. The figures are shown in the next table.

Four grouped companies.

	1923.	1929.	1929 as percentage of 1923.
Total number of ordinary passengers	633·4 m.	589·8 m.	93
Total receipts from ordinary passengers . . .	£55·4 m.	£48·3 m.	87

Thus there was a decrease of 43·6 million in the number of such passengers, and of £7·1 million in the receipts from them.

SUMMARY OF RECEIPTS AND EXPENDITURE.

SELECTED EUROPEAN RAILWAYS, 1929–1933.

Railway or Country.	Currency		1929 thousands	1930 thousands	1931 thousands	1932 thousands	1933 thousands
Belgian National Railway	Belgian francs	Rec.	3,546,695	3,528,540	3,090,730	2,451,978	2,329,917
		Exp.	3,066,823	3,208,358	3,023,944	2,620,480	2,342,960
Czecho-Slovak State Railways	Czecho-Slovak crowns	Rec.	4,888,543	4,628,512	4,362,972	3,490,352	3,135,516
		Exp.	4,447,197	4,521,131	4,183,938	4,043,031	*
France: Main Line Railways	French francs	Rec.	16,110,042	16,032,070	14,584,578	12,428,809	11,707,912
		Exp.	12,669,028	14,159,737	13,902,798	12,797,349	12,197,912
German Railway	Reichsmarks	Rec.	5,353,834	4,570,317	3,848,667	2,934,318	2,915,100
		Exp.	4,493,496	4,090,353	3,622,471	3,001,084	3,063,000
Great Britain: Main Line Railways	Sterling	Rec.	182,777	172,618	158,496	145,342	145,281
		Exp.	143,698	139,483	128,541	121,336	119,355
Italian State Railways	Lire	Rec.	4,980,704	4,600,066	3,853,470	3,345,882	3,055,854
		Exp.	4,379,832	4,124,730	3,573,490	3,218,465	3,190,138
Jugo-Slav State Railways	Dinar	Rec.	2,680,313	2,655,290	2,382,009	1,975,811	1,907,456
		Exp.	2,688,422	2,732,332	2,542,506	2,069,390	1,922,236
Polish State Railways	Zloty	Rec.	1,596,906	1,458,874	1,293,998	1,009,126	868,000
		Exp.	1,413,894	1,331,520	1,187,036	936,014	810,700
Swedish State Railways	Swedish crowns	Rec.	208,130	201,580	181,230	166,140	166,140
		Exp.	158,870	157,370	156,640	153,290	150,170
Swiss Federal Railways	Swiss francs	Rec.	431,357	420,546	389,450	342,953	335,844
		Exp.	280,382	291,420	283,282	273,301	262,566

* Not yet available.

Since 1929 road competition has become increasingly severe. It would seem fair to estimate, therefore, that in 1933 at least 15 or 16 per cent. of the total decline of 28 per cent. since 1923 is due to road competition, giving a loss of at least £11 millions due to this cause.

It is much more difficult to assess the loss of railway goods traffic due respectively to bad trade and road competition. Some indication may be obtained from a comparison with the Index of Production and the Quantitative Index of Imports compiled by the Board of Trade. These figures have been available since 1924, and between that date and 1930 the Index of Production of manufacturing industries rose from 100 to 106·3, while during the same period the Quantitative Index of Imports rose from 100 to 111·4. If we make the assumption that in the absence of road competition the merchandise and live-stock traffic receipts of the railways would have increased in approximately the same proportion, say by 6 per cent. between 1924 and 1930, these receipts would have increased from £51·6 millions to £55 millions in 1930. In 1930, however, they actually amounted to no more than £47·3 millions, representing, if this argument is valid, a diversion of £7·7 millions. In 1927 there was a general increase in freight rates of 7 per cent., and assuming that this did not cause a diminution in aggregate revenue, this would mean that the loss was the more significant. Since then, however, many rates have had to be reduced.

Taking passenger and merchandise traffic together, the total loss of net revenue to the railways due to road competition between 1923 and 1930 may be estimated at not less than £16 millions.

In order to view the position in true perspective, it is necessary to disgress a little at this point and consider the growth of road transport and the causes of its development from the side of the motor transport industry.

Since the war the development of motor transport has been remarkable. Though there were some 307,000 motor vehicles in use in Great Britain in 1914, the number had fallen to 189,000 in 1918, owing to the restrictions of the war period. The railway strike of 1919, however, greatly stimulated the use of motor vehicles and by 1920 the number in use had grown to 551,000. By 1923 it had soared to 1,131,000. In 1928 it was just over 2 millions, and it reached 2¼ millions in 1933.

Up to 1925 the most numerous category of vehicles was the motor-cycle, but since that year the number of private motor-cars has exceeded the number of motor-cycles. Motor-cycles increased in number continuously from 373,000 in 1921 to 705,025 in 1929, but in 1933 they had decreased to 540,594.

The growth in the number of private motor-cars as at August 31 in each year is shown in the following table :

1921	242,500	1928	877,277
1922	314,769	1929	970,275
1923	383,525	1930	1,042,258
1924	473,528	1931	1,076,128
1925	579,901	1932	1,118,521
1926	676,207	1933	1,195,882
1927	778,056		

The reduced horse-power tax on private cars, which comes into force in 1935, will no doubt serve further to stimulate the use of such vehicles.

There has been a similar continuous increase in the number of goods-carrying vehicles, despite the ups and downs in national prosperity. In spite of the trade depression after 1929 and the uncertainties caused by the publication of the Salter Report, the number of goods vehicles has continued to increase. The next table gives in each year the number of such vehicles in use in Great Britain as at November 30, the number licensed being greatest in this quarter of the year.

1923	183,250	1929	325,700
1924	212,300	1930	340,500
1925	234,200	1931	352,500
1926	259,000	1932	360,200
1927	282,800	1933	379,600
1928	301,500		

The last category of vehicle to which it is necessary to direct attention is that of Hackney Carriages, comprising taxi-cabs, motor-buses, and motor-coaches. In this class a noticeable feature has been the decline between 1930 and 1932. This is to be explained by the operation of the Road Traffic Act, 1930, which imposed restrictions on the use of motor buses and coaches. The number of hackney vehicles in use in each year in Great Britain as at August 31 is given in the next table.

1921	82,800	1928	93,429
1922	77,614	1929	95,798
1923	85,965	1930	98,865
1924	94,153	1931	86,208
1925	98,833	1932	84,667
1926	99,077	1933	85,352
1927	95,676		

According to statistics contained in the Reports of the Traffic Commissioners the number of passengers carried in public service vehicles was 5,269½ millions in 1931 and 5,418¼ millions in 1933, or approximately more than six times the number of passenger journeys by rail including season ticket holders. The average receipt per passenger journey by road was, however, only 2·66*d.* in 1931, and 2·57*d.* in 1933. The total passenger receipts were £58·4 millions in 1931, and £57·9 millions in 1933.

Apart from such factors as the exhaustion of the railways after the war, and the industrial disputes of 1919 and 1926, the striking growth of road transport has been due to a variety of factors, such as its mobility, flexibility, and convenience; a succession of technical improvements; the fall in the price of fuel and other costs (petrol cost 2*s.* 11½*d.* in May 1921, but in 1934 it cost only 1*s.* 5*d.* despite the addition of a tax of 8*d.* a gallon); and its lower charges for certain traffics.

The great convenience of motor transport has been a most important factor in the case of the private car. The advantages of having a vehicle which can be used when, where, and as the owner desires are obvious.

To commercial travellers, salesmen, etc., the motor-car is a most valuable help. Naturally this development has robbed the railways of much traffic which would otherwise have come to them, but which they are unlikely to regain. The effect is most obvious in the case of first-class traffic. There must also be a considerable loss of traffic to the railways during holiday times. On the other hand, there is no doubt that a big proportion of road traffic is new traffic which would not have developed without the motor-car.

The competition of the motor-bus and motor-coach has been most severe on local journeys, short distance travel, and cross-country routes, where the railway station is not so near, or the services less frequent, or the timings not so good. In these circumstances, partly through greater convenience, partly owing to lower fares, the motor-bus has established a definite ascendency and it will be no easy task for the railways to regain much of this traffic.

On the goods side the competition of road transport with rail has become intensified during recent years. Again, this competition is partly a matter of the convenience of road transport ; but it is chiefly a question of charges, especially in the case of goods placed in the higher classes of the general railway classification. Road hauliers have been able to quote low rates for the higher grades of traffic without any statutory obligation to carry commodities in the lower grades, such as ores, iron, coal, limestone, or road metal. Knowing both the standard and the exceptional rates of the railways from any station to any other, they can undercut the railways with a lower rate, and frequently base their charges on the existing railway rate.

Mr. W. V. Wood, a vice-president of the London, Midland, and Scottish Railway, has recently emphasised the probable effects of such competition. ' It is clear that the two systems cannot live together, and ordinary commercial considerations will force a levelling downwards of the higher railway rates and a levelling upwards of the lower railway rates, if the conditions governing the use of the public roads continue as now.'

The Road and Rail Traffic Act, 1933, which is now coming into operation, will no doubt tend to restrict increased competition from road hauliers, since before new licences to operate goods vehicles may be granted it has to be shown that there is a need for them, and the railways have a right to lodge objections. But it must be remembered that the Act permits what is called ' claimed tonnage ' to all existing operators. There can, therefore, be no immediate reduction in competition. Moreover the issue of ' C ' licences, that is, licences to those traders using road transport in connection with their own business and not carrying for others, may not be refused for either new or old tonnage, except on grounds of former bad conduct or failure to observe conditions. But, as stated in the Report of the Royal Commission on Transport, 80 per cent. of goods-carrying vehicles are owned by traders and manufacturers for providing their own collections and deliveries, and one effect of the 1933 Act may be to increase the number of traders who provide their own transport. There is here, therefore, a wide margin of goods traffic which may be still

further lost by the railways, or a similar margin that may be won back by them under favourable conditions.

Before the coming of the railways coastwise shipping used to be of the greatest importance to British trade, and during the nineteenth century it remained a formidable competitor to the railways. War-time conditions, however, transferred much of the traffic to the railways, and even yet coastwise shipping has not fully recovered from this set-back.

Nevertheless coastal shipping is by no means a negligible competitor with the railways since it is a very cheap form of transport. It has indeed been described as the British equivalent of the inland waterways of the Continent. It is particularly well suited to the carriage of coal (indeed 60 per cent. of the commodities carried coastwise consist of coal), and for the distribution of foodstuffs from ocean-going vessels.

Coastwise passenger services operate between London and Newcastle, Liverpool and Scotland, while goods services are very numerous. From Manchester, for example, cargo liners sail weekly to Aberdeen, Dundee, Leith, Kirkcaldy, Newcastle; and twice weekly to London, Glasgow, and Greenock. The coastal liner services are now utilising road transport to effect collections and deliveries, and in this way are able to give direct door-to-door services, for which through rates are charged. Containers are also being employed.

During recent years it would seem that the railways have lost some of their traffic to the coasting trade. In evidence before the National Wages Board a year or two ago, Sir Ralph Wedgwood stated that the railways had lost the carriage of two million tons of coal from the Midlands to the South in consequence of the competition of coal shipped coastwise from Northumberland and Fife. Coastal shipping rates, he stated, are now 16 per cent. below their pre-war level owing to the severe depression in the freight market.

A recent important development in the coasting trade has been the evolution of Diesel-engined shallow-draught vessels capable of working into the smaller ports of the country. Such ships are now regularly penetrating to such places as Norwich, Colchester, York, Selby, Lancaster, Bridgwater, Gainsborough, Truro, Penryn, Exeter, and Totnes. The total number of ships engaged in navigating shallow channels has of recent years tended to diminish owing to the 'scrapping' of obsolete sailing vessels, but, owing to the substitution of power-driven vessels of larger size, the volume of trade has tended to increase. The use of such craft has, for example, transformed Norwich as a port, and no less than 30,000 to 40,000 tons of sea-borne coal a year are now being carried into Norwich, whereas a few years ago the port was little used.

Some of the latest coasting vessels, though of 1,400 tons dead weight, have a draught under full load of somewhat under 14 ft., and can therefore enter ports formerly used by only the smallest coastal liners. The ships are fitted with the most modern equipment for the handling and stowage of cargo, and are therefore independent of the dock facilities—formerly a question of considerable difficulty. It is indeed true to say that the British shallow-draught coasting trade is being rapidly revolutionised.

Air transport is the third, and most recent, competitor with rail transport.

Its great advantages are speed and independence of the nature of the route traversed, since direct journeys over both land and sea are possible. In other countries, notably Germany and the U.S.A., air transport competition has been severely felt by the railways; but in Great Britain the comparatively short distances have prevented any rapid development of internal air transport lines up to the present year. The advantage of speed is somewhat reduced by the time taken to travel from the centre of towns to the adjacent aerodromes. In the table on p. 130 statistics are given relating to air transport in this country for the years 1929–33. It will be seen that the total mileage flown, even for 1933, amounted only to a little more than three million miles.

During the present year, however, great activity has been shown in the inauguration of internal air routes. In March 1934 a total mileage of approximately 5,000 route miles, or roughly a quarter of the railway route mileage, was contemplated by various undertakings taken together. Not all these schemes may come to fruition. Last year the mileage operated over regular routes was under 600 route miles. In previous years, therefore, the railway companies in this country had no occasion to take air competition very seriously, but profiting by their experience of road transport competition, and to be prepared, they obtained air transport powers in 1929. This year they have formed a new company—Railway Air Services, Ltd., in conjunction with Imperial Airways, Ltd.—for the operation of internal air transport routes.

Experiments made in the past have not been very encouraging, and last year, for example, the G.W.R. lost over £6,000 on its air service between Birmingham, Cardiff, and Torquay; while in 1930 the City Councils of Liverpool, Manchester, and Birmingham had to subsidise the internal experimental routes of Imperial Airways, Ltd.

In the past the best results have been shown where air transport could take shorter routes than the rail, or routes involving a sea passage—e.g. the air ferries between Bristol and Cardiff, Hull and Grimsby, Glasgow and Belfast, London and Cowes, Thurso and the Orkneys.

In August of this year Railway Air Services introduced a route between London, Birmingham, the Isle of Man, Belfast, and Glasgow, whereby it is possible to leave Glasgow at 9.15 A.M. and reach London (Croydon) by 1.30 P.M. Leaving London again at 3.10 P.M. one could be back in Glasgow at 7.30 P.M.

The importance of this year's developments are due to the employment of faster aircraft. The machines used in 1930 on the Manchester-London route had a cruising speed of 90 miles per hour, but to-day the machines which are being employed are capable of over 140 miles per hour. Another important development is the utilisation of these services by the Post Office for the carriage of mails.

If the new services commenced this year can survive as a commercial undertaking, a new era in British transport will have been inaugurated. But when full account is taken of all the costs of operation this is extremely doubtful, unless a subsidy in some form is granted them.

The decline in railway traffic which has taken place during the post-war years has been due, as I have said, to a variety of causes, including

		1929	1930	1931	1932	1933
No. of ' permanent ' licensed aerodromes at December 31		36	50	58	68	79
No. of pilot licences current at December 31	Class A	1,063	1,708	2,091	2,397	2,611
	Class B*	207	252	315	369	441
Membership of Aero Clubs	Total	3,873	5,808	6,572	4,629†	4,931†
	No. of members holding Civil Pilot's certificate	717	1,270	1,526	1,106†	1,569†
Registered aircraft (including Imperial Airways)	Total	600	846	924	981	1,055
	No. on regular services	28	35	35	42	60
Mileage flown for hire or reward on regular and non-regular services, passenger and freight traffic (including Imperial Airways)		1,388,000	1,437,000	1,604,000	2,090,000	3,075,000

* 25–40 per cent. of these pilots hold ' A ' licences also.

† These figures are not strictly comparable with those of the preceding years, since the membership figures of 7 aero-clubs under National Flying Services, Ltd., which ceased to receive Government assistance in July 1932 are excluded.

economic depression, the shrinkage in world trade, and competition from other modes of transport. It is a very difficult matter to disentangle the effects of the various causes, and no very definite conclusions can be reached on this point. The effects of road competition are, however, incontestable, and the abstraction of traffic by this competitor is reflected in the general trends in traffic statistics for general merchandise and passenger services during the post-war period.

Fluctuations in national prosperity are clearly indicated by variations in the volume of traffic (e.g. the peaks of 1920 and 1929 stand out clearly, as does the trough of the great depression), and these have affected traffic of all kinds. The improvement in the internal economic position of the country is definitely indicated in the monthly traffic statistics of the past year, but it cannot be expected that the prosperity of 1929 can be attained until the international trading position improves.

The chronic depression in the old pre-war export industries has naturally led to a fall in the traffic provided by them; thus even in the comparatively good year 1929 the tonnage of coal, coke, and patent fuel carried by rail was only 91·8 per cent. of that in 1913. By 1931 this traffic had fallen off by a further $33\frac{1}{2}$ million tons. Now coal traffic is practically immune from road competition, and it is only during the past few years that coastwise competition has become somewhat more severe. A considerable fall in other mineral traffic since 1913 is obviously due to a similar cause.

General merchandise traffic shows a fall of more than 10 million tons comparing 1929 with 1913, despite the fact that the industrialisation and population of the country has increased since 1913. In this case, there is no doubt but that road competition has been the prime cause of the loss of traffic. The considerable expansion in the lighter industries of Great Britain hardly appears to be reflected at all in railway traffic. These industries are well suited to road transport, and in fact many new factories are now built not at rail-side, but on the main roads and utilise road transport for all their requirements.

As regards passenger transport, the very marked decline in First Class travel from $23\frac{1}{2}$ million journeys in 1913 and $34\frac{1}{2}$ million journeys in 1920 to only $17\frac{1}{4}$ million journeys in 1929 is no doubt in large part—though by no means altogether—due to the increased use of motor-cars. The fall in Third Class travel (756 million journeys in 1913, 823 million in 1920, and only 657 million in 1929) is due to the competition of the motor-bus and motor-coach. In estimating the effects of road competition it must be remembered that it is not sufficient to measure the figures of to-day against those of 1913. The railways have failed to obtain their share of the new traffic which has arisen since 1913 owing to increase of population or from the tendency of journeys *per capita* to increase as the years go by.

The only direction in which rail traffic has definitely held its own is in parcels traffic. Season ticket travel by train, it is true, has increased since 1913, but the railways have not gained a proportionate part of the new traffic which must be very considerable bearing in mind the trend of population away from the centres of towns to outlying districts.

Turning next to consider the reasons why traffic hitherto rail-borne has been captured by other forms of transport, it is obvious that the effects of the war, though they gave the railways an advantage over canals and coastwise shipping, were responsible for a setback to railway efficiency, and thus gave road transport an opportunity to develop in its initial stages. Next the strikes of 1919 and 1926 resulted in the loss of much traffic to the roads and it is certain that much of this was never regained. The question of relative cost to the user has naturally been an important factor in determining the distribution of traffic as between road and rail, though it has not been the only factor. For many kinds of traffic, especially those placed in the higher classes of the railway classification, road transport except over long distances has been cheaper. Here we are faced with a fundamental difference in principle. The railways base their classification in the main on the value of the commodity, while road transport bases its classification on the cost of the service.

Relative costs to the user as between road and rail are affected by a variety of considerations such as transhipment, the degree of packing required, loading and unloading, the possibility of return loads, the volume of the traffic offering, distance, frequency of journeys, wage rates, and labour costs.

Road transport generally has the advantage where the haul is for short or medium distances, where return loads are available, where the articles require careful handling, or where the traffic passes in quantities sufficient for a van or lorry load. The advantages of road transport in regard to cost are, for example, well illustrated in the case of furniture removal, where road quotations in the past have often been very much below rail. The railways are now, however, trying to regain this traffic by means of containers.

Road transport has definite advantages for local deliveries and collections and for transit up to a certain distance, which varies with the nature of the traffic. On the other hand, beyond a certain distance for most kinds of traffic, for transport in bulk, and where certain ancillary services have to be performed, the rail has a definite superiority.

Cost, however, has not been the only factor in determining the relative economic spheres of the two forms of transport. As already indicated, speed, convenience, and incidental advantages have also to be taken into account. The motor vehicle is at the direct command of the user; it can readily be adapted to suit special requirements; there is a lessened liability to damage and pilferage; prompt service can be given; the goods can be loaded and unloaded by men conversant with the special requirements of the business. The location of the consignor's or consignee's premises may be a further factor affecting the choice of transport methods. Again, the motor vehicle has a considerable publicity value for certain traders.

On the other hand, the dependability, reliability, and speed of the railway, especially on long distances, gives it an advantage. The relative advantages are well illustrated in the case of perishable commodities. Fish traffic, for instance, which often goes long distances, and which must arrive in time for the market, goes by rail; fresh fruit, which can be sent direct by road from the grower to nearby towns, goes by road. Again,

long-distance milk traffic in bulk, generally, though not always, goes by rail; short-distance collections from farms or deliveries to neighbouring towns go by road.

In the case of passenger traffic, the road has gained most on the short haul. Motor-buses can be operated so as to give a more frequent service; they can go right into the centre of the towns, and they may pass by the door of the traveller. They do not require a very heavy traffic in order to prove remunerative. But on the long journey, the motor-bus is slow—even the long-distance express services in operation just prior to 1930 were generally competing with the railways in price only. Costs were low because of the user obtained from the vehicles and the cheap 'summer' tickets had not then been introduced. Road transport cannot deal so successfully with intensive passenger traffic as can the rail.

In the case of air transport competition depends almost entirely on speed. Air transport in this country shows to the greatest advantage where rail transport is slow because of roundabout routes or where transfer between rail and sea is involved.

It must, I think, be admitted that until the last few years the railways either did not realise the extent to which road transport was likely to develop or, at least, were slow to take steps to meet the competition which was arising. Prior to the advent of road transport the railways relied too much on their established position. They were inclined to wait for traffic to come to them, since in most cases no other mode of transport of equal efficiency was available. It is true they employed canvassers, but canvassing for traffic was not undertaken to the same extent or with the same zeal as it is to-day. The needs of their customers were not made a special subject of study. There was a tendency to wait for complaint to arise before altering an existing mode of operation or the kind of service offered, except in those cases where an operating economy to the benefit of the company was likely to be effected. Examples are not far to seek. On the passenger side they failed to see the latent demand for a more frequent service of trains at more regular intervals, especially on branch lines. On the goods side they took insufficient notice of the changes in the needs of traders. Owing to the more rapid changes of fashion, to the necessity of holding a greater variety of goods and at the same time keeping working capital low, traders to-day keep smaller stocks of each commodity. Frequently they need to replenish stocks at short notice, and consequently demand a more expeditious delivery of small consignments. In consequence of these changes, merchandise traffic by goods train has definitely tended to go in smaller lots, and in many depots the increase in the number of consignments per ton of goods handled has been remarkable.

These demands of the passenger and the trader are admittedly expensive to meet. The costs of providing such services with the existing equipment or mode of operation are higher than for the kind of service hitherto rendered by the railways. A monopoly holder under such conditions may refuse to supply the public with what it wants, but where competition exists a firm can only do so at the risk of being driven out of business.

It is true that the Railways Act, 1921, no less than the economic depression, made it incumbent on the railways to effect economies both in their organisation and in their mode of working ; and, as we have seen, in spite of the high level of their wage and certain other costs, they have succeeded in doing so to a marked degree. Yet I cannot help but feel that in certain directions economies have been effected at the expense of efficiency, though not, as the statistics show, at the expense of safety.

Within the last few years this policy has, however, been reconsidered. A considerable programme of re-equipment has been entered upon. Lines are being widened, new locomotives and rolling stock are being built, and smaller trains at more frequent intervals are being run on branch lines. There is every indication that this policy is to be actively pursued in the near future. The extension of electrification of lines is a special case in point.

Even more noteworthy are the attempts now being made to recover the goods traffic the railways had lost to road transport. Braked goods trains have considerably increased since 1928, giving a far quicker service from station to station. Containers for perishable goods, for furniture, and for special consignments of various kinds are now being increasingly provided, and suitable wagons built for their conveyance. Collection and delivery services at terminal stations have also been entirely overhauled and improved. The delivery areas have been extended. Feeder services for the collection of goods by road vehicles have been established in many centres, enabling the delivery of goods at their destination to be effected on the day following that of collection. The delivery of goods has also been expedited by the establishment of railhead or radial distribution centres from which goods are delivered over wide areas by fleets of motors, which thus save the delays of transhipment and quicken delivery.

Naturally, these new services have taken time to develop, and though it is still true that in certain cases consignments of less than wagon-load amounts are several days on the journey from sender to consignee, the average journey time of consignments on the railways has been greatly reduced.

A considerable change in the methods which the railways might adopt in dealing with road competition was brought about by the Railway (Road Transport) Acts, 1928, which conferred road powers on the railway companies. Under these Acts, each of the four grouped railways was permitted to own and operate road vehicles in any district to which access is afforded by the system of the company. The railway companies were also allowed to invest in any established road transport concern or to enter into agreements with any municipality, company, or other concern. Rates and charges, however, are subject to review by the Rates Tribunal on application by interested parties, and notice of any agreement must be given to the Minister of Transport.

Until these Acts came into operation the railways were fighting with one arm tied. The road arm is now free, and the railways have already shown that they intend to use it freely, not only where it is actually remunerative, but wherever it is felt desirable to improve efficiency and effect quicker delivery of goods. The liberty conferred on the railway

companies by the Acts is very wide, and except in the matter of charges for regular services—which will, it is likely, be always a minority of the services required—puts the railways companies in a position to compete with the road haulier with absolute freedom.

An ' ideal distribution ' of traffic would provide for an economically sound division of function between road, rail, and other forms of transport, and would take into account, not only the price to the consumer and the cost to the operator, but also the ultimate real cost to the community. Such an ' ideal ' division of function would provide that every passenger and every ton of goods would pass by that mode of transport or combination of modes which would provide the most efficient service at the least cost to the community. In this way overlapping, redundant, or unnecessary services would disappear, and each form of transport would convey just those passengers and goods for which it was best suited. Such a division of traffic between the different modes of transport would be determined by the demand of those who required it and the facilities offered by those who provided it, while the incidence of cost to the community should be such as not to involve the subsidisation of any one form at the expense of the others.

Sir Josiah Stamp, in his Presidential Address to the Institute of Transport, examined this particular problem from the point of view of expenditure of capital. He argued that if all forms of transport were subject to one authority, such a body would be failing in its duty if it extended one form of transport—other things being equal in the matter of service—instead of another which would have involved less expenditure or given better results for the same outlay. But, as he pointed out, under present conditions there is no guarantee that any one section of transport, in ignorance of the true costs or scientific position of the other, may not embark capital on projects which may be quickly rendered obsolescent by imminent advances elsewhere, or alternatively it may fail to embark capital for fear of obsolescence which in fact does not occur. We have, as he pointed out, not yet reached the stage where rival forms come together and agree that a particular piece of transport development should be undertaken by that form of transport which can do the work for least cost taking into account any public expenditure involved. He added that ' Even governmental application of capital to transport itself is quite empirical, especially if it has responsibility for one form and not for another. How much more is the application of capital by a hundred different agencies ? '

The difficulties of distributing traffic on any ' ideal basis ' has been strongly emphasised in the Final Report of the Royal Commission on Transport. ' But as things are to-day,' they ask, ' is such a state of affairs, or even any approach to it practicable ? Who is to decide, for example, what rail services are desirable in the public interest and what amount of coastwise shipping ? Or what goods should in the national interest be sent by rail, road, canal, or ship ? To propound the question is sufficient to bring home the immense difficulty which it involves.'

They suggested, however, a rough approximation to this position in one particular, since they were of the opinion that it is not in the national

interest to encourage further diversion of heavy-goods traffic from the railways to the roads. 'Such further diversions would add greatly to the expenditure on highways and tend to make the railways unremunerative, without conferring any commensurate advantage.'

The Salter Committee endorsed this view, and recommended that the Minister of Transport should be given power to prohibit by regulation (after consulting the Advisory Committee which they recommended should be set up) certain classes of traffic which are unsuitable for road haulage from being transferred in the future to the road. They added that there is room for a scientific inquiry as to the most economic form of transport for each class of goods, having regard to distance and other considerations.

The ideal distribution of traffic could only be brought about if it were possible to secure that each piece of transport service, by whatever mode of transport it was effected, was charged for at a rate sufficient to cover its true cost of production. But the difficulties of determining such true costs are very great indeed, and especially so in the case of both rail and road transport. On the railways it is impossible unless one makes large and arbitrary assumptions in the division of costs between different categories of traffic, yet requiring the same permanent way, much common equipment, and many common services. It is equally difficult in the case of road transport—as the Royal Commission on Transport and the Salter Conference realised—if one is to take into account a proper share, according to user, of the cost of construction and maintenance of roads, the cost of signalling road junctions, the cost of street widenings in cities, and the construction and maintenance of terminal and junction stations. It would appear that in both cases we can only approach the problem by empirical methods. The real cost of production eludes us.

To what extent is it possible for the railways to find some solution of their problem by an alteration of their present (statutory) system of charging? Such a step is advocated by many railway critics at the present time. The proposals range from a general lowering of rates and fares—based on the assumption that the elasticity of demand for rail transport is such that a higher aggregate net revenue would thereby be obtained—to schemes involving a revolutionary change in the general structure of railways charges.

Prof. Pigou, in his *Economics of Welfare*, makes a careful analytical examination of the contrasted methods of charging according to value of service and cost of service, and comes to the conclusion that the latter mode of charging would bring about a better distribution of national resources and thereby increase national welfare. But his argument is by no means clear, nor does he indicate how the system could be carried out in practice. He admits that to apply the system would involve a number of delicate adjustments, since rates would have to vary with the incidental costs attaching to each service, and with the time at which it is provided in relation to the peak of the load. To provide for these adjustments would often be, as he again admits, a very difficult matter, involving costly technique and account-keeping. Eventually, he compromises by stating that it is a matter of how near to the ideal of cost of service it is

desirable to approach, and of determining at what point the advantage of getting closer to cost of service is outweighed by the complications, inconveniences, and expense involved in doing so. Moreover, there is the point that any change-over to a system of charging based essentially on cost of service would cause a very considerable disturbance in the present distribution of economic resources and activities. Various economic equilibria have been established on the basis of the present system of charges—e.g. location of plants, organisation of the heavy industries, etc., all of which would be disturbed by such a fundamental change. The matter is, for example, linked up with our present export industries, since in the past the mainstays of our export trade have been the coal, iron, steel, heavy chemical, and heavy engineering industries, all of which obtain the advantage, under the present system of differential charging, of low railway rates. Obviously, a change of such magnitude would create great opposition from many people who would fear that their position would be adversely affected. There is, indeed, little doubt that public opinion would strongly resent any sweeping changes. On the other hand, should the nature of our export trade change in character in the future or should we develop our home markets at the expense of our exports, there would probably be less opposition to the change. Nevertheless, as Mr. Wood has indicated, some change in the structure of railway charges must be made, unless the competition between rail and road transport is put on a more equitable basis, or their competitive superiority in given cases can be more clearly established.

Prof. Pigou has emphasised the importance of the time factor in relation to peak loads ; but it is also necessary to consider the load factor itself. Some advocates of railway reform, such as Mr. M. F. Farrar, have based their proposals on a consideration of this factor. It must, I think, be admitted that the load factor, both in relation to time and volume of traffic passing in a given consignment or on a given section of line is of considerable importance. The influence of this factor is already seen at work in current railway practice. For though railway rates are based in the main on the value of the service, other factors are also taken into account. An example of the influence of the time factor is that of reduced fares on certain suburban routes for traffic outside the peak hours. The load factor is also taken into account in ‘ minimum consignment ’ rates, the rate for small consignments, and in those special or exceptional rates which are granted in consideration of the traffic passing in bulk—e.g. full wagon or full train loads.

The question is how far could the practice of charging according to the load factor be extended with advantage. Costs to a railway are at a minimum when its capacity is fully employed. It could, I think, be argued that charges should be varied according as the particular demand for transport services increases or diminishes the load factor. If certain traffics involve only the partial utilisation of equipment which nevertheless has to be provided—e.g. traffic passing in less than full wagon or full train loads, provision of additional terminal facilities, etc.—then it might be said that the charges should be higher than for traffic which gives a better utilisation of equipment.

In the somewhat analogous case of electricity supply, it is of interest to note that charges are more and more being based on considerations relating to the load factor. Electricity cannot be stored economically. Hence any demand that comes on at a peak hour has, so to speak, to have part of the capital of the generating machinery allocated to it. But if a new demand came on only between peak hours, this allocation would not be necessary.

It is conceivable that the system of railway charging according to the load factor may be taken more into account in the future ; but it is difficult to see how it could be applied as a universal method. It is still more difficult to see how it could prove a solution of the problems to-day confronting the railways. Road competition alone, and perhaps that of air transport in the future, not to mention the increasingly retail character of trade, would wreck any attempt to enforce a rigid adherence to this principle.

I see, therefore, no real solution of the problem along either of these lines. Meanwhile, there is considerable diversion of traffic from a more economic to a less economic mode of transport. How is this to be prevented ?

In a noteworthy article in the *Economic Journal*, June, 1922, on ' Communication Costs and their Inter-dependence,' the late Sir William Acworth drew attention to the uneconomic diversion of traffic which may occur when one form of traffic is subsidised by the State. ' There is,' he said, ' a real distinction between the cost of providing a means of communication which is of general—or at least of wide—public benefit, and the cost of its use, which normally benefits only the particular user.' If, however, in one case the user, whether passenger or trader, has to pay the whole cost of his use, including the cost of providing and maintaining the specialised road as well as the actual conveyance cost, whilst in another use he is called upon to pay either a conveyance cost only, or the cost of conveyance plus some of the cost of maintenance of the roadway, uneconomic diversion of traffic from one mode of transport to another is likely to occur. He quotes numerous instances of such diversions of traffic, not merely from railways to roads, but also from railways to canals or coastwise shipping.

' If it be reasonable to charge upon the user of a macadam road the cost of use only, there seems no a priori reason why a similar policy should not be adopted in the case of a rail-road.' He foresaw, however, the very great difficulty there would be in apportioning the cost of construction and maintenance to the users of the roads or other mode of transport. In the case of the roads, even if the capital cost incurred up to a given point were ignored—as in fact the Salter Committee later proposed that it should be—it would be a task of well-nigh insuperable difficulty to work out a new scheme of tolls or licences which would apportion the remaining costs even approximately and with only rough justice as between the many different classes of users.

His plea, therefore, is that the cost of construction of communications—using the term in a broad sense—together with the annual cost of their maintenance should be a State charge, undertaken in the economic interests of the whole community.

The adoption of such a policy would mean not only a drastic revision of the present system of road taxation, but also the handing over of the permanent way of the railways at a fair valuation to the State, which would then become responsible for its maintenance.

The difficulties of getting public opinion to approve such a scheme are obvious, and were fully recognised by Acworth himself. The railways are private enterprises, and the suggestion that the tax-payer or rate-payer should be called upon to pay any part of the cost of construction and maintenance even of new lines, much more of lines constructed in the past, 'would come as a shock' to the average Englishman, though both in Paris and New York, this has in fact been done in the case of urban lines. This would be the first difficulty. Nor is it likely that public opinion would be won over by the fact that both in this country and in the U.S.A. laws have been passed limiting the profits which railways may earn to a reasonable return on their invested capital.

But there is a further difficulty. It is obvious that if the railway companies were relieved of this part of their cost of operation, railway charges could be very greatly reduced. The capital expenditure of the four grouped companies to December 31, 1933, on the lines open for traffic or under construction amounts to £795 millions. Interest on this sum at 4 per cent. would amount to £31·8 millions. Maintenance of way and works amounts to £16·8 millions. Though a considerable reduction would have to be made from both these items in respect of works which are not part of the permanent way, it is clear that the railways would be able to make sweeping reductions in their charges and yet earn their full standard revenue, as fixed by the Railways Act, 1921.

But would this in itself secure that economic distribution of traffic, both of passengers and goods, as between competing modes of transport, which is the distribution desired? Though it would remove some glaring inequalities, as between road and rail, it would not really effect the object Acworth had in mind. The cost to the State in providing and maintaining the communications for each mode of transport might easily prove to be heavier for a unit of transport work undertaken by one mode of transport than by another. Nor is it easy to see how the State might so adjust the scales that traffic—having regard to the kind of service required—would pass by the most economic method. In the absence of such adjustment the economic loss to the community would be considerable.

Whilst, therefore, we can agree with Acworth that 'it is incumbent on the Government so to shape its policy as to encourage that means of communication which in each case is on the whole the most economical to the community at large' and that 'to permit individual users to employ a means of communication which, though the total cost is greater, is cheaper to them because they can impose on the tax-payer or rate-payer a portion of the cost is economically unsound,' yet we cannot but feel that a solution of the problem is not to be found along the lines he indicates.

Nor do I think a solution is to be found in an attempt to bring about some rational and economic division of traffic as between rail and road, as was advocated by Mr. G. Walker in his paper to this Section at Leicester last year. Under his scheme the railways would be considered not as a

whole but by sections, distinguishing those sections which could and those which could not be worked profitably under a revised scheme of charges dictated not by adherence to the general railway classification, but by the exigencies of the situation, the charges being higher where the traffic is light than where it is heavy. The profitable lines would thus, he claimed, be able to earn a reasonable net revenue. The unprofitable lines would be closed down and their capital cost written off. The areas of the latter would then become entirely dependent on road or other modes of transport. It is even asserted that, of the 20,000 route miles, as much as 10,000 miles might have to be closed, and that, in fact, the only lines to be kept open might be the main lines between large towns.

The adjustment required from the road transport industry would be equally drastic. Under such a scheme it would be required to serve only those routes, or areas, where traffic is both light and irregular, and where return loads are not by any means certain. Each mode of transport would have a virtual monopoly in its own area.

It is hardly necessary to dwell on the opposition which such a division of traffic would call forth not only from the railways, but from the road hauliers, and, more important still, from the traders. It is sufficient criticism of such schemes to say that they fail to take account of the great diversity in transport needs, and in the most economic methods of meeting them. As modern practice is increasingly showing, a combination of rail and road transport is often the most efficient and economic method of meeting a given demand, particularly in the case of small consignments the delivery of which is urgently required. Moreover, it would entail carrying by road in certain areas, traffic for which road haulage is unsuitable and uneconomic ; or in other areas sending goods by rail for which rail transport cannot give the kind of service required.

It is not, therefore, by division into areas or spheres that the problem can be solved. Both rail and road transport are necessary in all areas, except those of very sparse population. The decision as to which shall be employed for a given piece of transport must be decided by relative efficiency and relative cost in meeting the demand. The two modes of transport must necessarily be in constant competition with each other ; and it is desirable that they should be so. The real problem is whether those costs can be sufficiently nearly determined in any case to decide which is the more economic.

A new phase in the competition between rail and road transport has arisen as a result of the Road and Rail Traffic Act, 1933. Under section 37 of Part II of this Act, a railway company may, subject to the approval of the Railway Rates Tribunal, make such charge or charges for the carriage of the merchandise of any trader, as may be agreed upon by the Company and the trader. Such ' agreed charges ' must, however, not be approved by the Tribunal if the object may, in its opinion, be secured, having regard to all the circumstances, by the grant of appropriate ' exceptional rates ' as provided for in the Railways Act, 1921. Moreover, it is important to note that a railway company in respect of an ' agreed charge ' is exempt from the obligation to make equal charges to all persons under like circumstances, and from the obligation to accord no undue preference

to any person or firm. The consequences of this to traders will be considered later.

Already over 100 applications for 'agreed charges' have been made, and a large number have been sanctioned by the Tribunal. Judging from the number of inquiries received by the railways, this system of 'agreed charges,' which may take the form of a flat rate on all the traffic of a firm, irrespective of distance or the diverse nature of the goods, would seem to offer definite advantages to a number of traders. The agreements so far made include a provision that the trader should hand to the railway the whole of his traffic to which the 'agreed charges' are applicable. In one case—one of the greatest interest—the charge is based not 'per package' or 'per ton' but on an *ad valorem* basis of 4¼ per cent. of the total value of the goods purchased by the trader. Such a basis of charge, whilst not unknown in the case of road haulage, is a distinct innovation in the case of railways. It is obvious that these 'agreed charges' may help to reduce accounting and clerical costs both to the trader and the railway company. But to the railways the main advantages are that they will secure additional traffic and eliminate the risk of further diversion to road transport. The provision in the Act of 1933, which made these charges legal, was inserted as a result of an adverse judgment by the Railway Rates Tribunal in 1932, in the celebrated 'Robinson Case' when an agreed charge in the form of special exceptional rates proposed by the Great Western Railway was refused on the ground that these were not new exceptional rates within the meaning of the Railways Act, 1921. The Act of 1933, therefore, relieved the railways of a statutory limitation which did not apply to their road transport competitors.

If the number of successful applications for 'agreed charges' is any indication, it would seem that this new system of charging is likely to be considerably extended, especially in the case of the larger traders. It is a development of the utmost significance in the history of rail and road competition. The system of differential charging prescribed by Parliament in the earliest Railway Acts, and continued in successive Acts, had already been seriously undermined by the great extension of 'exceptional rates,' despite the attempt in the Railways Act, 1921, to reduce their number by the device of increasing the number of classes in the general railway classification from 8 to 21. 'Agreed charges' are a still greater departure from the principles of that classification.

The result of a large extension of the system of 'agreed charges' will undoubtedly be still greater competition with road hauliers, and much of this cannot fail to be extremely wasteful to the community. But the effect on traders generally is even more serious. If the railways make individual contracts with particular traders, others in the same line of business will no longer be able to rely, as they have been able in the past, on non-preferential treatment. The appropriate flat rate to one trader may, owing to the different nature or scale of his business, be higher than the flat rates to one or more of his competitors. Hitherto he has been able to rely on the fact that one of his costs—his costs of transport—is identical with that of the others in the same place in competition with him. This may no longer be the case in rail rates, just as it has not necessarily been

the case with road transport charges. That the traders realise the consequences of this is clearly seen in the evidence given by them and various trade organisations in the course of the hearing of the Robinson and Woolworth applications for agreed charges.

The traders are, in reality, on the horns of a dilemma. They cannot ask that the railways should be tied to their former methods of charging while they themselves are free to choose road transport when it suits them to do so, and at the same time to fall back on rail transport when it does not suit them, or when it is more expensive to use the roads. In the past the traders have had the best of two worlds by utilising road transport for the delivery of their high-valued manufactured products and rail transport for their coal, raw materials, and even returned empties.

What then is the solution of the problem? How can the trader's position be best safeguarded and at the same time wasteful competition between road and rail be minimised—a competition which will become more intense with the extended use of agreed charges? How can the real needs of the country in the way of transport be best and most economically met?

It would be a foolish and retrograde solution to suggest—though this has secured approval in certain countries where state railways have been protected by the governments—that the great advantages accruing from the development of road transport should be forfeited in the interests of the railways. These advantages should be secured to the community except where they are clearly uneconomic in character. The railway companies in effect admit this, as is shown by their own increasing use of road transport either alone or in conjunction with the rail, not only in those cases where they have to meet road competition, but in cases where this method gives a better or more economic service.

The best solution that I can see is that the railways should cease to be regarded as merely railway companies—which as a matter of fact they have long ceased to be, as witness their numerous and well-developed ancillary undertakings such as hotels, docks, canals, housing estates, associated air and road transport services, and numerous other undertakings. They should come to be regarded as transport companies, undertaking a given piece of transport by that means or combination of means which appears to them (however impossible it is to ascertain real relative costs) to be the most economic and, at the same time, most suited to meet the real demand of the traveller or trader.

But this solution would mean the absorption of road passenger and goods services—where undertaken for hire or as public services and not performed by a firm for the transport of its own commodities—by the new 'transport companies.' There would naturally be much opposition to this solution, and public opinion would have to be educated.

This, however, is the solution of the problem which has been adopted by the Irish Free State. The Transport Act, 1933, of the Irish Free State provides, subject to the approval of the Minister of Transport, for the compulsory acquisition of all road transport agencies by railway or shipping companies.

It is significant, too, that a similar solution has been recommended by

Sir Felix Pole in his Report of July 21, 1934, to the government of Northern Ireland, who had requested him to submit recommendations for co-ordinating road and rail transport in that country. He advises the formation of a Road Transport Board to include all road transport services, both passenger and goods. Further, he recommends that the Board should be compelled to pool its revenues with the railway companies. He was deterred from recommending a single Transport Board, combining both rail and road transport, only because this would involve special difficulties due to the fact that six of the railway companies operate both in Northern Ireland and in the Irish Free State. Sir Dawson Bates, the Minister for Home Affairs, has since anounced that the Government have decided to adopt the main principles of Sir Felix Pole's report. 'The Government,' he said, 'have come to the conclusion that the only practicable method of achieving the object we have in view is to bring the two systems of transport into partnership with a common financial interest, and to get them to work together instead of against one another, so that the best features of both may be used in one system.' It is understood that the necessary legislation will be introduced in the spring session of Parliament. The formation of the London Passenger Transport Board was also a step in the same direction, though, as its name implies, it is limited for the most part to the carriage of passengers only.

If the scheme proposed as a solution, namely, the formation of 'Transport Companies,' were adopted, it might also be necessary to include air transport operating on internal routes. But this should not be difficult since the railways, as we have seen, already have an interest in some of these services.

In this way all the means of land transport would come under unified management, leaving competition only between land transport and canal or coastwise traffic. This is capable of being distributed on a more economic basis under competition than in the case of road and rail, and it could therefore be left to the forces of competition. It would thus be left to the transport company to decide whether a given piece of transport should be effected by rail or by road, or by a combination of the two, but with due regard to the service required by the community. Obviously it would be to its own interests to effect it by the most economic method. Its own net revenue will be diminished by mistaken methods. And though, as we have seen, it will still be impossible for it to work out exact costs of operation, either for rail or road, it should be able to do so approximately on certain general assumptions based on experience, and in this it will be appreciably helped by the fact that both methods of operation are within its own control.

This solution involves, of course, a considerable degree of monopoly. The fact has to be recognised. But it should be remembered that in this matter transport would only be adopting in its own special way the method of rationalisation that has had to be applied in different ways and in different degrees to other industries.

The interests of the community could be safeguarded. The principle of limitation of profits could be applied to the new transport companies as it was applied to the railways in the Railways Act, 1921, and as it is

applied to other public utility undertakings. Provision would have to be made so that the companies would share in increased profits or reduced costs due to greater efficiency of operation.

The main difficulty would, of course, be to ensure that the monopoly companies should be kept to a high degree of efficiency, and that they should continue to meet in a satisfactory way the real and ever-changing transport requirements of the community. This might be effected by a transformation of the Railway Rates Tribunal, which no longer performs any vital function, into a statutory body charged with the express duty of seeing that the transport companies are working with due economy and efficiency and at the same time meeting the reasonable and legitimate demands of the travelling public and those engaged in industry and trade. Such a body should have power, with certain safeguards, to compel a reluctant company to institute a change in its services or methods of operation. There would remain, too, a certain check on efficiency, since it is not proposed to restrict the use of private motor-cars or traders in the use of their own road vehicles for the purposes of their own business.

Despite the development of the new forms of transport, railways still remain the backbone of the transport services of the country. They are likely to remain so for many years to come. They are still the most economic mode of transport for many purposes. But to meet modern requirements, they need to be supplemented by other modes of transport. This, I venture to think, can be done most effectively and economically when the different modes of transport are under one management.

SECTION G.—ENGINEERING.

SOURCES OF CHEAP ELECTRIC POWER

ADDRESS BY

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For many years the extravagant waste of our coal has been the subject of criticism. The steam engine, the blast furnace, and the domestic fire consumed it recklessly, and thermal efficiency was formerly disregarded. To-day we are more careful of our fuel, except perhaps in the domestic fire, but there is still a considerable and unnecessary waste at the very beginning. The amount of combustible material left in the mine, dumped at the surface as useless, or burnt at the pit-head to get rid of it, has often been pointed out, but its poor quality and large proportion of dirt make its transport to a consumer unprofitable, or render it unsuitable for use. The latter disability has been largely overcome by various devices in the boiler-house, and to-day we see steam raised by stuff that would have been scorned by our predecessors. But the material must be used on the spot, and the Commission called together by Mr. Lloyd George ten years ago advocated a comprehensive if rather shadowy scheme for generating electric power at the pit-head. The saving in coal was clearly demonstrated, but the financial advantage was not so convincing.

The last ten years have brought about great changes in the conditions, some favourable to the scheme, some diminishing the financial advantage, and the question requires reconsideration under present-day conditions, with, if possible, a forecast of future developments.

The general idea of the scheme of production of electric energy here proposed takes as its basis the complete linking up of all parts of the country by the grid and the subsidiary lines fed from it or from the stations directly. All stations are connected to the grid, and as well as supplying their local consumers, put the additional power into the grid as required. This is the well-known main function of the grid. It is here submitted that this leads to a different scheme of generation from that now followed, and that sources of cheap power are rendered available that previously could not be utilised economically.

The questions to be considered are :

(1) The proportion of consumers who are within economic distance of a pit-head station.

(2) The quantity of very cheap coal that is available.

(3) The relative advantages of widely spaced large stations and more numerous small stations.

(4) The opportunity offered by the grid to bring into economical use pit-head stations at small isolated mines, power from factories using industrial steam, power from coke-oven and blast-furnace gas, and hydro-electric stations.

(5) The cost of transmission of electric power as compared with the carriage of the equivalent coal by rail or ship.

(6) The effect of a substantial reduction in the cost of generation on the cost of distribution and the selling price of electric energy.

The first question to be considered is whether pit-head production will so much limit the position of the sources of supply as to involve a great distance of transmission to a large part of the population.

If a distance of forty miles be regarded as still in the neighbourhood of the coalfields, a map of the coalfields shows that most of Great Britain is within this distance. A line across Scotland from Montrose to Arrochar on Loch Long is the northern boundary, and a line from Hull to Bournemouth, and up to Taunton in Devon, marks the southern and eastern limits. A small part of Wales is also outside. Two-thirds of the population live in the area, and if London be omitted as a special case, only one-fifth of the rest are outside. There is also a probable coalfield in Lincolnshire, which if it materialises will bring in a good part of this fifth. To a large extent, the population has gathered round the coal pits, and there are practically no large towns, except seaports, that do not lie within easy reach. A scheme depending on nearness to coal pits will have a large field for its operations, and it will in no way act prejudicially on parts which it may not be able to benefit.

It is proposed to use the lowest grade and waste coal, and the proportion required may be up to 10 per cent. of the total coal raised. If the outputs of the different areas be examined, it is found that this proportion will in all cases be adequate for the population of the area. In some areas—Durham, S. Wales, and part of Yorkshire—where there is much less waste coal, the quantity of coal raised is so large that not more than 2 per cent. will be required, which is easily provided from waste.

The belt of coalfields which lie about 120 miles from London can provide enough for their own people and still have an excess of some three million tons per annum of cheap coal, which will suffice for London at present, but is not enough for the future. Hence London and the south may require a proportion of sea-borne coal. There is ample Midlands coal, but its use will entail the consumption of qualities for which a good price can be obtained for other purposes, and it will be a question of relative cost of sea-borne coal and electrical transmission. The prospective Lincolnshire field may solve the question in favour of direct supply from the pits.

Inside the area the pit-head station will be more economical than the present stations. There are seventy or eighty selected large stations within the area, some with no river, many with rivers that will not suffice for a largely increased station, so that the sites have little to recommend them except nearness to large towns. They were advantageous in early years, when their cooling water was adequate and distance of transmission was an important matter ; but their future will be without these advantages, and their huge consumption of coal will make them undesirable neighbours in cities. Railway and canal facilities for coal transport were also attractive factors, but these disappear if it is cheaper to convey power electrically than to carry the equivalent coal over the distance.

Any wholesale sudden change of the existing state of things would

certainly involve more loss of central station capital than the economies would repay, but in view of future expansion there seems a need for an examination of the present policy, which is only the old isolated station plan with interconnection by the grid superimposed. The opportunities afforded by the grid permit of a great change in the general plan, and a change, moreover, that can be introduced by gradual steps, if the final scheme is outlined at the beginning. The present rate of expansion indicates that in ten years' time the station power will be at least double its present figure, and while the utilisation of spare plant which the grid permits will slow down the increase of plant for two or three years, after that the normal growth will give opportunity for a new policy. There may be some waste of capital, where stations have been designed with a view to large expansion, in that certain permanent parts are now unnecessarily large ; but the proportion of such parts, taken all over, is only a small item, which the saving in fuel costs will quickly repay. No scrapping of existing plant need be done unless there will be a gain by so doing.

Waste Coal.

The term 'waste coal' will here be used to include all coal in the seam that is not at present sold, but is or can be brought to the surface, and coal of poor quality that will be profitably used in the pit-head station, instead of being extensively cleaned for sale. This quantity varies with the kind of seam and with the purpose for which the coal is used. In Durham and S. Wales, where much of the coal is converted into coke, there is little waste, as even small fragments can be coked, and the coal is won with small admixture of dirt. But in most other parts the dross has a larger ash content and is less saleable. Machine cutting produces a larger proportion of dirt than hand winning, some of the mixed coal and dirt being left in the pit as not worth raising, but the actual cost of working is much less. If a use is found for the waste, this disadvantage of machine cutting will be removed, and the full advantage of the reduced cost of cutting will be gained, while no coal need be lost.

The use of dry-cleaning processes results in a rather larger proportion of waste than does the wet process, and if this waste has no value, the cheapness of the process is neutralised by the loss of coal ; but again a use and a market for the waste will be in favour of dry-cleaning. Wet processes are from one aspect a wrong action. The water that is unavoidably left in the coal and often ignored is quite as detrimental to the calorific value as an equal percentage of ash. It is just as useless as fuel, and it has further to be evaporated, in which process it absorbs 1100 B.Th.U. per pound, whereas one pound of ash would require to be heated to a temperature of about 2000° F. to absorb that amount of heat. There is, of course, the additional trouble of removing the ash, but the avoidance of water in the dross and small coal is a definite advantage. Hence dry-cleaning will be more widely adopted if the waste can be used. The waste from dry-cleaning is often cleaned again and some saleable coal recovered, but if the whole waste has a value and is used, the cost of additional cleaning will be saved.

Of the dirty coal that is at present raised and remains as the residue of cleaning operations, some is dumped on to waste land and some into

the sea, but the greater part is burnt in the furnaces of the mine power station. The consumption is wasteful in the extreme, for burning is the cheapest way of getting rid of the otherwise useless material. About 6 per cent. of the coal raised is used to produce steam for power to work the mines, whereas in a colliery where the coal is scrupulously saved and there is little waste, it is found that the fuel required is only 1·25 per cent. of the coal raised, and the quality of it is exceedingly low. Hence some 5 per cent. is immediately available for other purposes if it is used economically, to which can be added what is actually thrown away.

Summing up all these actual and prospective sources of low-grade coal, it may be estimated that if an overall price of 5*s.* per ton at the cleaning floors were offered, in most districts a quantity equal to 10 per cent. of the coal raised would be readily obtained, with a smaller proportion in the rest, and that this would yield some 18,000,000 tons per annum, with a calorific value averaging 10,000 B.Th.U. per lb. This is 50 per cent. more than is used to produce the present output of all the generating stations.

Any arrangement by which a waste product from one industry is used in another requires some plan to prevent an excess or deficit in the product. In the present case an adequate supply of fuel is essential, as the sales of electricity cannot be controlled. There is, however, an elastic amount of product, for the coal on the boundary line may be either used in the station or given a cleaning process, and a greater quantity will be available at a small increase in the price. The figure of five shillings will include much coal that now has almost no value, so it will also cover a fair proportion of coal of a higher value.

The daily variation in the load curve requires no great storage, but the Saturday and Sunday demand must draw from a store, if the colliery raises coal on five days a week, as is usual. The seasonal variations will, to some extent, balance, for though the domestic load is less, the domestic coal demand is also less, and the waste coal corresponding to this will be reduced. But seasonal and trade fluctuations can be adjusted by altering the amount of boundary line coal.

The general scheme should permit of using the waste coal from as many pits as possible, including even small isolated mines, for they assist in supplying the grid at points otherwise unprovided for, and reduce the distance of transmission. What the lower limit of economical pit station will be need not be elaborately discussed, for the isolated pits provide only a small part of the total coal, and their exclusion does not materially affect the available supply. As their small stations will have a larger cost of interest on plant, they will be advantageously allowed to run at full load, putting all their excess power into the grid. The wages costs will be little more than their present figure for boiler and steam engine attendants. In each case it will not be difficult to determine whether to include them as supplying stations, or to supply them from the grid and discard all coal that is quite unsaleable, or finally to leave them to use their waste coal as at present. The quantity and quality of the available coal, and the position of the pit, as regards other pits and as regards neighbouring consumers, will be the deciding factors.

The greater part of the coal raised comes from pits which can be

grouped together, and it is becoming more the custom to bring the coal to a central point for cleaning, which will facilitate the use of the waste coal. If the figure of 10 per cent. is taken as a working hypothesis, then a station of 100,000 kw., working on a load factor of 0·4, will use per day some 700 tons of waste coal, and will require a total output from the cleaning plant of 9,000 tons per day over the working week. This is not an exceptional quantity, and any additional advantage in grouping will tend to increase the custom.

The scheme will evidently provide an important amount of cheap fuel, and will permit of power stations of a size that ensures a low figure for cost of plant and running costs, so that the low price of the fuel is not offset by any increase in cost in other directions. It is true that the stations will not be placed in the towns, and to that extent distribution costs are increased; but, on the other hand, land is cheaper, and it is being found that a station consuming many hundred tons of coal a day will compel the use of expensive remedies against sulphur and dust, so the advantages of an urban site will be sensibly diminished. Moreover, most of the large towns are not far from coal mines, and the cost of transmission will be very small. With pit-head stations of the 100,000 kw. size the economy is easily determined, for all working costs other than fuel will be practically the same as those of existing stations, if the latter were designed and built to-day.

There will be doubtless a good many stations of smaller size, in which there will be some increase in the capital cost per kilowatt and in wages. But down to a size of 30,000 or even 20,000 kw. the influence will be slight. Coupled by the grid or other lines to neighbouring stations, they will not resemble the existing stations of this size, but will contain perhaps two generating sets of 10,000 kw. and boilers to correspond, so that the present figures of increase of cost per kw. with decreasing size will not apply. It will be economical to put all necessary spare plant into the large stations, and the equipment of these smaller stations can be simplified. Their cost of production will therefore be little different from that of the larger stations, and will be substantially lower than the best of present-day large stations.

An actual example will show what can be done in a pit-head station equipped with efficient modern plant and run with economy on very low-grade fuel. It is only 4,000 kw. in two sets, working at a load factor of 0·7. The coal used contains 40 per cent. of ash and moisture, a very remnant of fuel, and is given in the colliery accounts a rather exaggerated value of 3*s.* per ton, corresponding in calorific value to a good steam coal at 4*s.* 6*d.* The consumption corresponds to 1·5 lb. of steam coal per unit delivered, notwithstanding the small size of the sets and the absence of a supply of water for condensing purposes, and the whole cost of fuel, wages, maintenance, and supervision, with interest and depreciation at 9·5 per cent., is not more than 0·137 pence per unit delivered. It will be shown below that the usual cost for the largest stations to-day, on the same charge for interest and depreciation but with normal coal, is at this load factor 0·185 pence, so that even small stations, suitably designed, can be usefully brought into the scheme. This particular station corresponds closely to what is proposed for isolated

pits, for it works in conjunction with the supply company of the area, delivering its excess power into the mains, and relying on the mains for unusual overloads or possible breakdowns.

Condensing Water.

An argument that has frequently been brought against the pit-head station is that there is little likelihood of a sufficiency of cooling water for the condensation of exhaust steam, in order to produce the high vacuum that the turbine can make use of. The cooling tower provides water that is still a little warm, and the condenser pressure is 1·5 lb. instead of 0·5 lb. But the gain in efficiency due to the high vacuum is often exaggerated by failure to apply comparable conditions and to take recent improvements into account. For a given turbine taking a given amount of steam and suitably modified in the final stage, a reduction in back pressure adds a definite amount of power. Also a rise in the initial pressure, again with suitable design, gives a definite increase of power for the same steam. Hence the effect of the improved vacuum is large if the initial pressure is low, but it becomes less and less as the boiler pressure is raised, and with 350 lb. initial pressure the actual loss of power due to a back pressure of 1·5 lb. instead of 0·5 lb. is theoretically only 5 per cent., and in practice the full expansion of the whole of the steam to 0·5 lb. is not economical, so that the actual saving in fuel is barely 4 per cent. This is certainly not sufficient to condemn a plan which can offer other advantages. The case of Hams Hall station, in Birmingham, is of interest on this point. It has 30,000 kw. generating sets, working at a load factor of 0·32, and consumes the equivalent of 1·35 lb. of good steam coal per unit delivered, attaining an overall thermal efficiency of 23·34 per cent. on the units generated. Though it works entirely on cooling towers, and the turbines are not of the largest size, its economy can hardly be improved upon. It may be claimed that the absence of cooling water can be definitely disregarded as a disability in the use of pit-head stations.

Industrial Steam.

Another source of cheap power may be found in the proper utilisation of industrial steam. Many industries need low-pressure steam in their processes, and use boilers working at a pressure of 50 lb. or less. There is no difficulty in producing steam at 350 lb., superheating it, and passing it through steam turbines, to exhaust at the required low pressure, and the steam so delivered is in all respects as good as that produced directly from boilers, as it does not come into contact with lubricating oil. The thermal efficiency of the turbine is 100 per cent., less the small radiation losses and bearing friction, for the rejected heat of the exhaust steam is used for the other purposes, and all steam friction loss is retained as heat in the steam. As compared with the coal used in the boilers to produce the low-pressure steam, taking into account the cooling and running losses of the turbine set, the extra boiler losses due to the higher temperature, and the higher pressure of the feed pumps, the additional coal works out at 0·4 lb. per unit delivered. The additional capital charges are also low, for there is no condensing plant, the turbines are

cheaper, the boiler plant requires a different and rather more expensive type of boiler, but not a larger output of steam, much of the subsidiary plant is the same as before the change, coal-handling plant being larger, water supply and handling are unchanged, boiler-house staff is little increased, and engine-room staff and plant are the only complete additions. The result is that capital costs for the additional plant are, overall, not more than half of those for the complete plant in a corresponding supply station, additional repairs, wages, and management also one-half, and coal not more than one-third of that in the best supply station. Hence even a small station of this kind can operate at a very low figure, little more than 0·1 pence per unit, and the works in question will obtain their own mechanical power at this very favourable price. The only difficulty in the plan at present is in the utilisation of the surplus power. The works require a supply of steam depending on their processes, and if this is to pass through the turbines, the electrical output is fixed not by the consumers but by the process steam. An isolated plant cannot cope with two independent and variable loads, except by complex by-pass contrivances, steam accumulators, additional plant for evenings and Sundays and so forth, entailing so much extra cost and loss that the advantages are dissipated. On a large scale the method is highly economical, and is well exhibited in the Billingham works of Imperial Chemical Industries. If, however, the factory electric station is connected to the grid, even a small one may put in all its spare output, no matter how irregular that may be, provided that consumers are not too far away, and that it can supply the energy at a price which will benefit all parties.

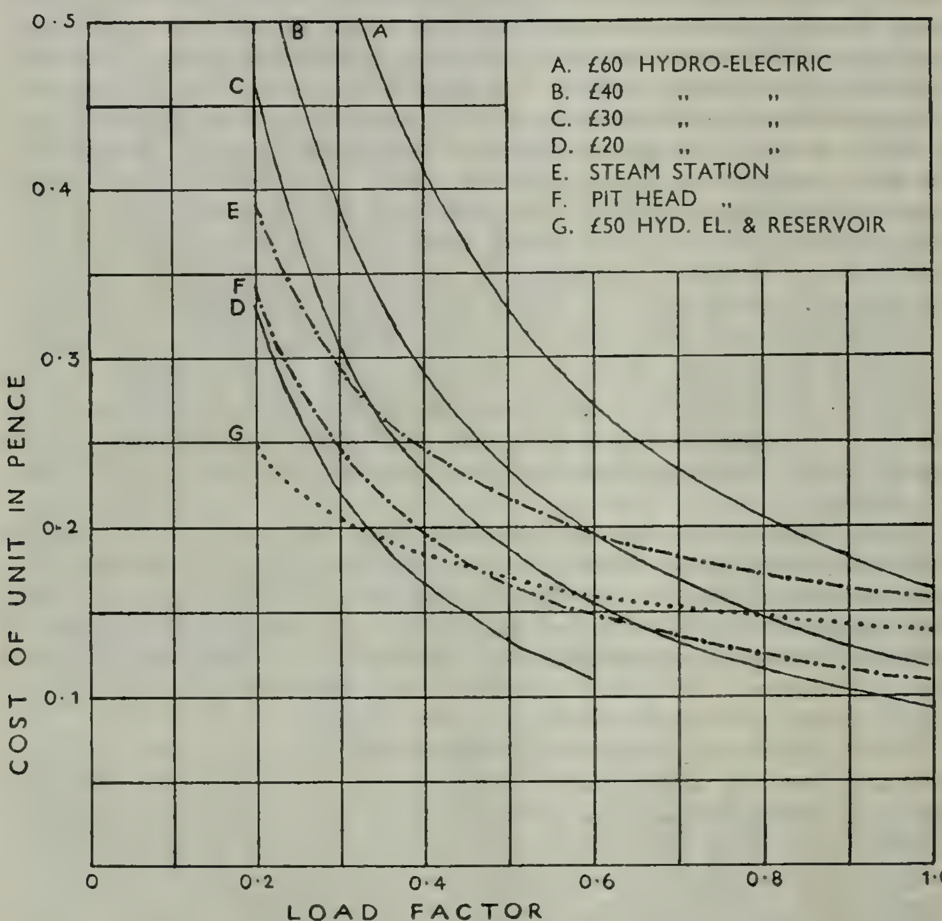
How much power can be obtained from this source it would be laborious to ascertain. Each factory would require separate consideration, and the cost of altering existing boiler plants would be important. But the change can be introduced gradually, new factories or renewal of plant affording opportunities, until all suitable factories are absorbed into the scheme. By that time the increased demand will easily take up all the power without disturbing the other sources.

Other possible sources of cheap electric energy are coke ovens and blast furnaces, both of which produce combustible gas. The coke-oven gas has a high calorific value, and will command a better price if distributed as town gas. The proposal to transmit town gas at high pressure to considerable distances, if it prove successful, will allow of the direct use of very large quantities of gas, if of high calorific value. It is not worth while to transmit the low-grade gas from blast furnaces, just as it does not pay to carry low-grade coal, and the gas may therefore drive electric plant, and all power in excess of works requirements can be put into the electric mains. This has been in operation at the North-Eastern Supply Company for many years, and while no great amount of power can be expected from this source, all cheap electricity at distributed points is helpful. The stations would operate like the small pit-head and the process steam stations, the output being controlled by the supply of gas and not by the consumer, so as to avoid the storage of gas.

Two large consumers of coal are probable in the near future, the one being the proposed petrol factory, the other the low-temperature

carbonisation process. But neither is likely to provide low-grade coal. While only high-grade coal is used for actual hydrogenation, there is consumed a large quantity for heating purposes, and this may be of very low grade, if the works are near the pits, so at present there does not seem likelihood of the new industry providing power for the grid. The production of low-temperature carbonisation fuel provides a good gas as an additional product, which should be distributed as suggested above. While a fairly good coal with low sulphur and ash content is

FIG. 1



required for actual conversion, there is here also an additional amount used for heating, which can be low grade, and if the works are near to the pits, they will absorb all the refuse coal belonging to the coal that is coked. While this industry should have an important future, if properly organised, it does not seem likely to come into the electric supply scheme.

The items in the cost of a unit have of recent years been codified and separated into parts dependent on the load factor and those that are independent, together with the influence of the size of the station. The costs for a normal station of 100,000 kw. and for a pit-head station of the same size are here given, assuming certain conditions. The capital

expended on the plant is, one quarter $4\frac{1}{2}$ per cent. debentures, one quarter $5\frac{1}{2}$ per cent. preference shares, and one half ordinary shares expected to pay 7 per cent., or 6 per cent. all over. Depreciation and reserve are $3\frac{1}{2}$ per cent. The cost per kw. of the normal station is £14 per kw., and of the pit-head station £15. Coal is 13s. per ton at 11,500 B.Th.U., and waste coal is 5s. at 10,000 B.Th.U. Salaries, wages, repairs, maintenance, and stores are the same for both, and are at the average rates for this size of station. All charges for rates and taxes, office expenses, and other general expenses are omitted.

The curves are shown in Fig. 1. At all load factors the reduction in cost at the pit-head station is about one-twentieth of a penny per unit. While this reduction does not look impressive when compared to the usual charges for lighting, it makes a substantial difference to the cost of the unit for domestic heating, which is now down to 0·5 pence in some places ; and it will be shown that any lowering of cost of production is followed by a decrease in cost of distribution, so that there will be a beneficial improvement on the first economy.

[More recent figures of steam station costs show reductions in wages and repairs amounting to some 0·01 pence per unit, varying very little with the load factor. This correction lowers the curves for both normal and pit-head stations equally, so the saving due to the pit-head station is not altered.]

Water Power.

In England there is at present no question of electric supply of any magnitude from water power. The Severn scheme is receding into the background, as the cost of generation from coal goes steadily down. When the Association met in Edinburgh in 1921, this Section devoted some attention to water power, and no one ventured to prophesy so great a change in every item in the cost of production from coal as has actually taken place.

The chief part of the cost of water power lies in the civil engineering work, for the water turbines, now reduced in cost and improved in efficiency, are financially an unimportant part. There is a dead weight of capital expended on permanent works, and their very permanence is against them. Repayment charges may be put low, but they remain while the rival steam stations are installing cheaper, larger, and more efficient machines, and reducing fuel, wages, and capital charges. In Scotland these years have seen the planning of several ambitious schemes, some of which have been undertaken and are nearing completion. As engineering work they are well conceived and in every way excellent, but already their expected production costs are being hard pressed by their rivals, and the end is not yet. This paper shows that substantial reductions are quite feasible, in addition to the gradual reductions that have gone on steadily and show no signs of ceasing. In the Highlands and everywhere north of the industrial belt from Glasgow to Fife, excepting the large towns on the east coast, the hydro-electric station is in a strong position, for its foot is on its native heath. But in the Lowlands and in coast towns obtaining sea-borne coal, in the author's opinion it is fighting a losing battle.

The cost of a hydro-electric scheme cannot be given a single figure

per kw., depending only on the size. Even the actual station plant varies in cost according to the head of water, while the pipe lines, lades, and reservoirs may have a wide range, so that each proposed scheme must be considered individually for capital expenditure. Station wages are small, as the machinery is simple, but the upkeep of the hydraulic works is usually a substantial item, and one which depends largely on the results of natural phenomena, which cannot be foretold. The load factor introduces complications, differing with different types of layout.

For comparison with steam stations, all wages, salaries, and maintenance, i.e. all running costs, are taken at 14*s*. 6*d*. per kw. per annum, the load factor having very little effect. The corresponding figure for the steam stations described above is 18*s*. at a load factor of 0·7, and 15*s*. 8*d*. at load factor 0·4. Or the cost per unit for the hydro-electric station at load factor 0·4 is 0·05 pence. Capital charges are 6 per cent. as before, and depreciation and reserve are put at 2·5 per cent., instead of 3·5. All rates, taxes, etc., are omitted as before. The curves for varying load factor, worked out for a range of capital costs per kw. from £60 to £20, are shown in Fig. 1. The power is taken as that which the station has normally sufficient water to supply continuously, and the actual annual output falls below this if the load factor is less than unity, due to variable demand or to shortage of water.

At the usual load factor of 0·4, the scheme is limited to £32 per kw., if it is to equal the normal steam station, and to £25, if it is to compete with the pit-head station, disregarding all question of transmission. A cheap design is one in which the river is diverted into a channel or tunnel, and after some distance sufficient head is obtained above the river bed. No storage is attempted, and during periods of low water the output falls off and must be supplemented from a neighbouring steam station. Its use corresponds to what has been suggested for small pit-head stations. The Clyde Valley stations are of this character, and at their cost of £27 per kw. they compare favourably with the normal steam station if the load factor exceeds 0·3, but they require a load factor of nearly 0·6 to reach the pit-head station cost. The load factor in this case is really the river factor, which varies between a wet and a dry year, but they are certainly more economical than the normal steam station.

For stations with reservoirs the cost usually rises considerably, although that at Kinlochleven has exceptionally low cost and large storage. But such stations may be used in a different way. The daily fluctuations in load make no appreciable difference to a reservoir, and if the pipe line to the turbines is short, the extra cost of increasing the power of the station is small, for it only means larger pipes and larger turbine sets, which are cheap machines, so the cost per kw. of station power may be much reduced. The annual output is not increased, as that is limited by the water supply, but the station can operate more economically at low load factors, and it becomes a good peak load station. The cost curve is much altered in character, and an arbitrary example is given for comparison. The cost is divided into two parts, £36 being constant for all load factors as representing the reservoirs and collecting lades, and being calculated on the power at unity load factor, as determined by the annual quantity of water. Station and pipe cost at this power is

£14 per kw., and this is recalculated for each load factor, the station wages and maintenance also being adjusted. The curve is much flatter, and from 0·5 downwards its costs are lower than the pit-head station. Although at unity load factor the cost per kw. is £50, this reduces to £23 at 0·3 and to £18·5 at 0·21 load factor.

The stations of the Galloway scheme are to be mostly of this type, but the costs, when analysed in this way, are considerably larger, in fact 50 per cent. larger. The estimates given by the promoters in the parliamentary inquiry bring out the cost per kw. at £27 at a load factor of 0·21, at which it was proposed the stations should work, and the cost per unit on the above basis of calculation comes up to 0·34 pence, which is also the figure estimated by the promoters. The pit-head figure is 0·32 pence, so that in its own area and for peak loads there is little difference, though with higher load factors the pit-head station rapidly gains. The neighbourhood is, however, quite unable to absorb the 100,000 kw., which it is proposed to develop, on peak load or even as a complete load. It has been suggested that power can be transmitted to Carlisle, which is 50 miles away, and this, as will be shown below, will add 0·022 pence to the cost, if the load factor is 0·21. This brings the total to 0·36 pence, nearly the cost for a normal steam station. As Carlisle has a coalfield on each side of it, the advantage of the transmitted power becomes rather illusory, and the grid will not be greatly helped by the scheme, except in Galloway and Wigtownshire.

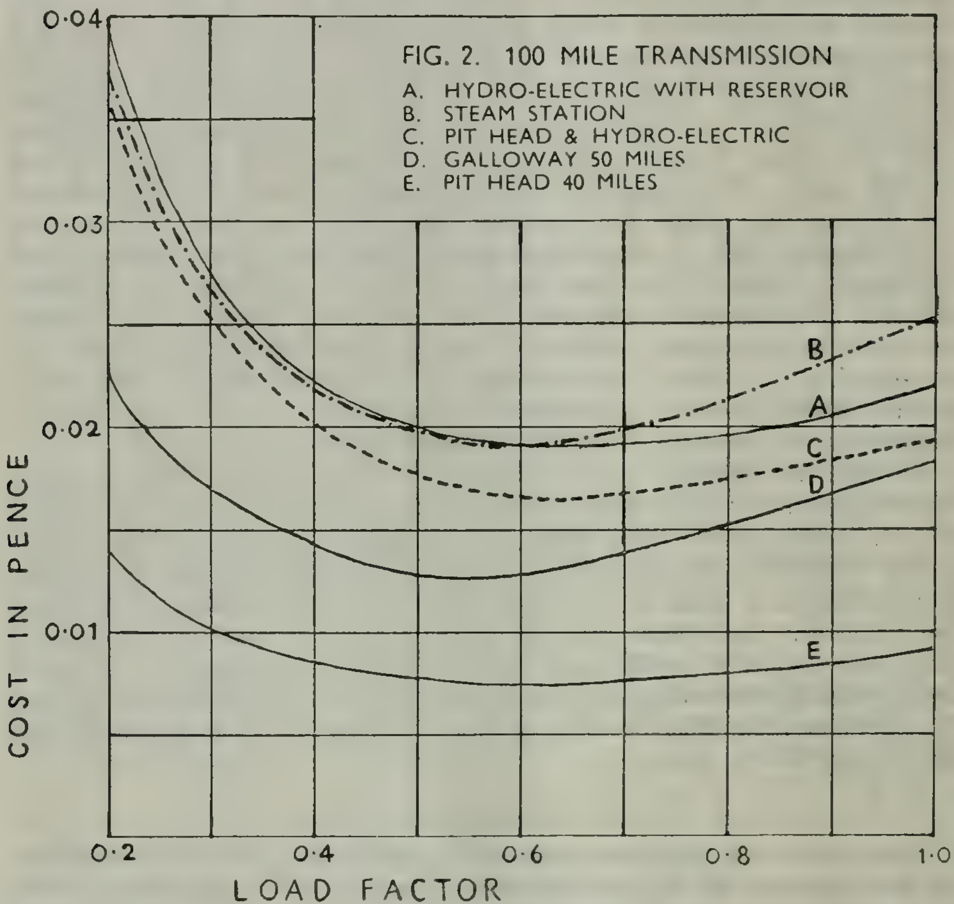
It might be imagined that with cost curves of different shape a happy apportionment of loads would yield a lower combined cost. It will be found, however, that little difference is made if the average load factor is not below 0·4, for the steam station curves are becoming flatter, and the reduction in their cost is absorbed by the higher cost of the peak load station. Each case must be worked out for itself, as no general rule can be given, and there are too many variables to allow of a mathematical determination of the conditions for a minumum cost, but in most cases the effect is disappointing, and the more so the higher the load factor of the system.

Cost of Transmission.

The position of generating stations brings in the cost of transmission. In the coal areas the numerous sources of supply will on the whole reduce transmission costs, but the supply of power to outside areas depends chiefly on the cost of electric transmission, as compared with other methods.

The cost of long-distance transmission of electric energy has been much reduced by increased voltage, and by reduced cost of transformers and transforming substations. It is considerably influenced by load factor, for capital charges and wages are constant, while line losses are much reduced on low load factors. For any distance of importance the grid at 132,000 volts will be the usual means, and the cost of transmission over 100 miles is shown in Fig. 2 for the various generating stations, the difference being caused by the respective costs of the power wasted in the line. The conditions assumed are—interest at $3\frac{3}{4}$ per cent., repayment in thirty years, and annual upkeep at £20 per mile, which makes a total

capital and maintenance charge of 6·75 per cent. There is 10 per cent. drop on full load at power factor 0·8 in the line and transformer windings at each end, and core losses are 1·25 per cent. At unity load factor the energy loss is directly subtracted from the station output, and must be charged at the cost of production, as given in Fig. 1. For lower load factors the exact figure to be allowed is not more than this, and is probably slightly less, but as the loss is small, the unity load factor value for the units loss has been taken all through for the coal stations and for



the £40 hydro-electric station without reservoir. But the station working on a reservoir has only a certain amount of energy per annum to sell, and the wasted energy is charged at the value for the load factor, which increases the cost at low load factors. Below 0·6 there is little difference between them. There is a definite minimum at about 0·6, which can be shifted to a lower load factor by increasing the load and line loss, if this does not cause regulation troubles. There is also shown the cost of transmission over 50 miles from the Galloway stations, and the cost over 40 miles from a pit-head station, which was the distance taken above as in the neighbourhood.

These costs may be compared with the cost of rail and of sea carriage of raw coal. Rail transport is in general one penny per ton mile plus

sixpence for end charges and waggons, or 8*s*. 10*d*. for 100 miles. Allowing 1·3 lb. per unit the cost is 0·061 pence, which is three times the cost of electrical transmission at a load factor of 0·4, so the coal waggon cannot compete with the grid. For shorter distances the proportion is slightly different, but always much larger. Carriage by sea is cheaper for long distances, if both pits and generating stations are conveniently situated. From Newcastle or Fife to London, for favourably placed pits, the cost is at present about 4*s*. per ton, so that electrical transmission from the nearest existing pits to London, 120 miles, will cost very nearly as much as carriage by sea to stations on the Thames banks, and only the cheapness of waste coal will give an advantage. Shipping freight charges are low at present, and a rise will make electric transmission economical to London, apart from the use of cheaper coal. Hence transmission from the pit-head stations may be safely undertaken, even if the amount of waste coal available should not suffice for the whole load, and if the Lincolnshire coal materialises, there will be plenty, some of it at a shorter distance.

Rates and Taxes.

In the foregoing calculations of costs, the item of local rates has been omitted, for rates vary in different districts, and a general figure is not possible. The present charge for rates on electric supply stations is very high, and they have not come under the recent reduction of rates on machinery. Roughly, the item of rates on the generating plant alone amounts to about 0·06 pence per unit, considerably more than wages and salaries, and more than half the cost of coal. It is a tax or contribution towards local expenditure, which has grown to dimensions far greater than the early years of its operation seemed to indicate. While generating costs have gone down, taxes have gone up, and this charge is not generally realised, except by the engineer who is trying to reduce costs, but it amounts to nearly £100,000 per annum for a 100,000 kw. station. Now and again a few thousand pounds of credit balance in the year's working of a station belonging to a town council is handed over 'for the relief of the rates,' and often there is much protest that this is obtained at the expense of the consumer. The far larger sum quietly extracted as rates is not called in question. While the theory and practice of rating, as applied to factories and public utility companies and services, cannot be discussed here, it may be permissible to claim that the position of electricity and gas supply and railways has become anomalous. The supply mains are also assessed for rates, so that the total rate charge to the consumer is often as much as 0·1 pence, while the selling price for domestic heating is 0·5 pence or little more. Without demanding the complete abolition of rates on these public industries, we may reasonably claim some substantial reduction, such as one-half, amounting in our case to 0·05 pence per unit. If to this is added the equal sum which the cheap fuel of the pit-head station can achieve, a total reduction of 0·1 pence is obtained. The importance of this will now be discussed.

Future Consumption.

The cost given in Fig. 1 for generation in large steam stations is 0·25 pence per unit at the usual load factor of 0·4, while the selling price is at

least 0·5 for domestic heating, power being 0·75 to 1·0, and lighting threepence to sixpence. Local rates account for some of this difference, but distribution and office expenses are the chief part. Both are nearly constant expenses for a given maximum demand, and are directly reduced by a high load factor. The mains do not wear out faster if they carry current for more hours a day, nor does it cost more to read a larger number of units on the meter, nor to make out a larger bill. Also the cost is decreased by a greater density of load over an area. More consumers per mile of low-tension cable merely mean more feeding points and larger high-tension mains or a higher tension, and to obtain a more nearly universal demand and a larger demand per house is simply a matter of reduction of selling price, while they will themselves help greatly to reduce the cost further, if the process can once be started.

The historically first use of electric energy—electric lighting—is now so general where a supply is available, that no great increase will be obtained by a reduction in price, and enlargement of areas of supply means country districts with sparse population. Motive power in factories is now supplied to the extent of one-half from electric mains, and a considerable part of the other half is electric drive from private plant, where industrial steam is required and a steam generator is easily added. These may come into the general scheme, but will not greatly increase the public demand. The old shop engine is rapidly disappearing, and the process will not be much accelerated by cheaper electricity, as in the great majority of cases the electric drive from a public supply already costs less than the shop engine.

There remain as comparatively little developed directions for new demand the fields of domestic heating of all kinds and electrification of railways. In these a successful competition with other methods depends largely on cost. Electric cooking, hot water supply, and house warming must be brought down to a figure not greatly exceeding that involved in the consumption of raw coal, if anything like a general adoption is to be brought about. A figure of one halfpenny begins to be persuasive, but above that the added convenience does not outweigh the cost in the view of most people, and even that figure only meets the competition of gas on equal terms, if the price of gas is eightpence per therm, and there are signs that this may be reduced. The possible demand is enormous, for the present consumption of domestic fuel is some forty million tons per annum, more than three times the whole of the coal used in electric supply for all purposes. Owing to the large losses of energy in the steam engine, with boiler losses and transmission, at the best only 20 per cent. of the total heat in the coal burnt is delivered to the consumer. The domestic fireplace has a rather better efficiency, but it is not used so economically, so on the whole the amount of coal used will be much the same. The station uses a cheaper fuel, but loses on the cost of distribution. As domestic heating yields a high load factor, and offers scope for a high density factor, it will help greatly in lowering distribution costs.

The railways offer a large, though not so large a field. This was explored by Lord Weir's committee of 1931, and the finding was favourable. But it was not universally accepted in its entirety, and the margin of advantage claimed was obtained by economies of doubtful

character. The price of electric energy was taken at 0·5 pence per unit, and at that figure the electric power came out at little less than the cost of present methods. Since then locomotive designers have not been idle, and coal consumption has been reduced in the latest patterns, so that a substantial reduction on the halfpenny will be required. This should be quite possible, for the price that was assumed was on the safe side and could be reduced to-day, since distribution costs in bulk to the railway line will be less than to individual householders, and the further reductions indicated in this paper will bring the question to a practical proposition. The complete electrification was estimated to require a consumption of 5,400 million units, but probably a good many branch lines would not be electrified, and a total of 4,000 million may suffice. It is not a great addition to the total load, which was close on 16,000 millions last year, but it is a desirable increase, as it will have a good load factor and can be easily provided, for railways and population go together.

There are signs that a low price will bring in large consumers in the metallurgical industries. The use of electric furnaces is rapidly increasing, and below 0·5 pence the private plant has little chance of competing, if complete reliability is to be ensured. The possible magnitude of this load it would be futile to estimate, but it will be considerable and will have an excellent load factor.

From the foregoing it is evident that the electric supply industry can be put on the road to a substantial and even to a great increase, and that the new business will materially improve the load factor and reduce costs of distribution. The use of cheap fuel and an alleviation of the burden of rates will give the initial stimulus that is needed, and the great increase will automatically recoup the apparent loss to the rate fund of the local authorities.

These prospective new consumers will reduce the amount of waste coal that will be available, for house coal and railway coal are high-grade fuel, from which a good supply of low-grade coal has been screened off. If they are taken out of the class of raw coal consumers, and put into the class which uses electricity, the effect will be twofold. But there is little chance of a wholesale complete electrification of dwelling-houses, and a complete cessation of the use of raw coal for any purpose. And under most circumstances it will be cheaper to use the coal at the pits than to carry it to supply stations at a distance, even though some of the coal is of good quality. There are many possibilities in the future, such as petrol and tar extraction and gas production, but for all of them it is preferable to avoid carriage of raw coal, so the pit-head electric station will always be in the right place, able to work in with the other processes, so long as coal continues to be our main source of power, and that is a long time.

Conclusion.

To sum up the main theme, the grid and the branch lines should operate not only as distributors of power to the consumer, wherever he may live, but also as collectors of power wherever it may be obtained, and like all successful middlemen, it should buy in the cheapest market and put the consumer into connection with the nearest producer, whether

small or large. The small producer, in other goods as well as electricity, may show very low costs of production, but fail to find a steady market. The grid can offer such a market, and while it has no warehouse or other means of storage, it can harmonise the consumer and producer by varying the output of the large stations, which will work on the principle of keeping up the pressure at distribution centres, and the current will flow naturally to where it is demanded. The stations will gradually be placed where their costs are lowest, and the pit-heads and coal-cleaning floors will be their natural sites for the greater part of this country. The economies thus made possible will attract consumers that are at present in doubt, and a great increase will ensue.

The process of introducing these new supplies need not be sudden or simultaneous at all parts, nor need the existing stations be hastily discarded. What is required is a policy of making all extensions of power at pit-head stations, and allowing a natural development of this policy as is found good. The closing down of the present small stations, and the normal rate of growth, will give opportunity for a large-scale trial in a few years, and commencing with the most suitable places, the process can be steadily continued. Every improvement in methods of transmission will place the pit-head station in a stronger position for the supply to large towns.

The question of the ownership of these large pit-head stations will require consideration. Several solutions are possible, but for all of them it is essential that there shall be co-operation between the producers of coal and the producers of electricity. The one party must be assured of a steady sale of their cheap fuel, that they may be willing to remodel their business to suit the new outlet ; the other party must be assured of a steady low price, that they may not be exploited after they have given hostages by large expenditure on the new stations. It seems a suitable case for a central control, as without guarantees neither party would be wise to commit themselves, though the advantages to both seem fairly certain and considerable. A proposal of such wholesale common action would have seemed impracticable ten years ago ; but we are becoming used to Central Boards, and the Coal Board and the Electricity Board are already in being for the purpose.

To the owners of large generating stations these proposals may appear rather alarming. The supply companies in whose areas are coal-pits will be able to put their new stations at the pits and reap the full advantage, and they constitute the majority. The others will have the choice of importing a bulk supply, if it is cheaper than their own product. The case of the large cities in the coal areas, which have their own stations but no pits in the city area, presents some difficulty. Sooner or later their stations may be outclassed by foreign imports. But it must be recognised that there is nothing permanent in engineering, least of all in electrical engineering, and a fitting motto for the supply industry may be taken from *In Memoriam* :

> ' Our little systems have their day ;
> They have their day and cease to be.'

THE USE AND ORIGIN OF YERBA MATÉ

ADDRESS BY

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PRESIDENT OF THE SECTION.

Infusions from vegetable products are common throughout the world, but the particular infusion with which this paper deals is that procured from the leaves and shoots of the *Ilex paraguayensis*, a shrub indigenous to Paraguay and to southern Brazil. After a process of drying, aided by fire, hot water is poured on the broken or powdered leaf, and the infusion is imbibed through a tube of silver or of native bambu. From the centre of its origin it spread rapidly, like all valuable food products, to Argentina, Chile and Peru, and, especially since the war, when many South American contingents were engaged, it has become more familiar in Europe than formerly.

The particular virtue of the drink is that it contains little or no tannin, combines favourably with a meat diet, and can be repeatedly refreshed by hot water without deleterious effects. In South America, especially amongst the Gaucho class, it used to take the place of fruit and vegetables, for it is an antiscorbutic of considerable value. Thousands of tons are used in South America annually.

Mixed with cold water, it provides a very refreshing beverage, but the normal method of taking the drink is in the hot infusion. When lukewarm it is regarded as a violent aperient. Two appliances are used, the *maté*, a gourd or silver cup in which the decoction is prepared, and a tube, the *bombilla*, through which the infusion is drunk.

The word for the receptacle (*maté*) became transferred to the leaf and the drink; both are now generally known under that name, especially in Europe.

The first mention of the drink in published literature occurs in a book by Nicolás Durán, a Jesuit missionary in Paraguay in the early seventeenth century. Durán travelled through the province of Guaira and visited the Jesuit missions at Villa Rica, San Xavier, Loreto and San Ignacio; all these regions were, at that time, centres of *yerba maté* preparation and of distribution.

Translated from the Latin, Durán writes as follows:

'The most severe labour to which the Indians are put consists in being sent by their masters to Maracaiu, to collect the foliage of certain trees growing in the mountains and forests. These trees, not unlike laurels, but

of a brighter green, flourish especially in moist and swampy woods. The leaves, after being parched in a fire, are pounded in mortars, and, when reduced to dust, are packed in cases, and carried many miles on the backs of the Indians. On account of the unhealthiness of the climate, and the scarcity of food, which their poverty-stricken masters cannot provide, these unhappy Indians are forced to subsist on snakes, grubs and spiders. And so, worn out by contagious diseases and famine, they die. It is a pitiable picture, for, in return for their labour, all they receive when they return from this slavery is a beggarly two yards of cloth. Some even go home empty-handed, because the Spaniards themselves are extremely poor. The Spaniards sell the powder of this herb (which they call " Herb " *par excellence*) to traders who come hither (Guaira), or rather exchange it for necessaries. And it often happens that 2,000 lbs. of this powder is given for a suit of common cloth, or 500 lbs. for a hat. Spaniards and Indians of both sexes drink this powder, mixed with hot water, once or twice daily, which proves a most efficacious emetic. So much are they slaves of this habit, that they will barter shirt, trousers or bedding for it. An instance is known where a woman stripped her hut of its roofing in order to buy this herb. They say too that their strength fails, and that they cannot live, if they are deprived of its use. The Indians take it at daybreak and at frequent intervals during the day. It has come to be such a vice in these provinces that all the inhabitants of the River Plate, Tucuman and Chile make use of it. So that in Potosí, and throughout Peru, 1 lb. of this herb is sold for four golden crowns. This herb makes men gluttons, slaves to their bellies, and renders them averse to work of any kind. And its efficacy appears to lie more in the imagination of him who uses it than its own inherent virtue.'

By the middle of the seventeenth century, Nicolas del Techo (du Toict), who became Superior of the Province of Paraguay, as a Jesuit missionary, writes of the use of the drink as follows :

' In Paraguay, for a long time, sugar and cotton, both produced in small quantities, were the chief wealth, till the leaves of a certain tree, growing in marshy grounds, commonly called the Herb of Paraguay, began to be in esteem. These leaves they dry in the fire and reduce to powder ; then, mixing with hot water, the Spaniards and Indians, both men and women, drink of it several times a day ; and, vomiting it up with all they have eaten, they find it creates an appetite. Many things are reported concerning this powder or herb ; for they say if you cannot sleep, it will compose you to it ; if you are lethargick, it drives away sleep ; if you are hungry it satisfies ; if your meat does not digest, it causes an appetite ; it refreshes after weariness and drives away melancholy and several diseases. Those who once use themselves to it cannot easily leave it, for they affirm, their strength leaves them when they want it and can't live long : and so great slaves are they to this slender diet, that they will almost sell themselves rather than want wherewithal to purchase it. The wiser sort (tho', moderately used, it strengthens and brings other advantages) will hardly ever make use of it ; and, if immoderately used, it causes drunkenness and breeds distempers, as too much wine does. Yet this vice has not only overrun Paraguay, but Tucuman, Chile and

Peru. And is near coming over into Europe ; this Herb of Paraguay being valued amongst the precious commodities of America. At first the Spaniards were well pleas'd with their cotton garments and liquor made of honey. But afterwards, trade enhancing the value of this herb, covetousness and luxury encreas'd, to feed both which the Indians began to be enslav'd to make this powder. Labour made their numbers decrease, and that made the Spaniards poor again ; to show us that very often the same methods we take to gather wealth serve to impoverish us.'

The two quotations given above are couched in rather harsh terms in regard to the excessive use of the ilex ; but the same could be written of tea, or any infusion, or of alcoholic drinks if taken in excess. However, Southey, writing in 1817, avers that over-indulgence has been known to result in almost total mental aberration, lasting over many days ; and the danger of serious infection, owing to the use of a common *bombilla*, which passes from lip to lip, is emphasised by many writers. Demersay adds that the constant imbibing of hot *maté*, alternating with draughts of cold water, is bad for the teeth, and suggests that the use of a silver *bombilla*, which can become unbearably hot, may cause cancer in the lip.

As regards the properties of the ilex, which have won for it so widespread a popularity, authorities are not quite in accord. Christy (1880) states that the leaf contains ' the same active property as tea or coffee, in a proportion (nearly 2 per cent.) intermediate between the two ; a volatile oil ; 16 per cent. of an astringent principle ; and about 10 per cent. of a nutritious gluten, only a portion of which is dissolved in the infusion. He states further that the full benefit of the leaf is only obtained when it is chewed.

The *Handbook of Paraguay* (1894) gives the analysis as 0·45 caffeine, 20·88 caffeo-tannic acid, an aromatic oil, gluten, and a proportion of theine. However, we may conclude that the action of the infusion would be that of a cardiac and a nutritive, while the relatively small proportion of tannin would render it more digestible than tea. It is, perhaps, a little strange that the earliest authors who record its use, Durán (1626–27), Leon Pinelo (1636) and del Techo (1649–72), quote it primarily as an emetic.

To leave aside for the moment the question of the actual discovery of the properties of *yerba maté*, the initial exploitation of the ' tea ' was undoubtedly due to the Jesuit missionaries. The first Jesuit reservation was founded in 1609, the last in 1760, and the Jesuits were expelled in 1774. The missionaries encouraged the use of the leaf among their Indians, to whom it was served out with other rations ; and Endlicher and Martius state that this was done to wean the natives from over-indulgence in fermented drinks. But there is no doubt that the revenues derived from the trade in the leaf became indispensable to these self-supporting communities, whose establishment is one of the most remarkable developments in the world's history. On the expulsion of the Jesuits their mission houses and lands became Crown property, and the *maté* industry had become so prosperous that, in 1807, the profits derived from it were reckoned at £100,000 annually.

Long before this, in the seventeenth and eighteenth centuries, the leaf

had become an article of trade to the western provinces of Argentina, to Uruguay, Chile, Peru, Bolivia and Ecuador. The chief collecting region was the Maracayu district. Asunción was the outlying depôt, whence the produce was sent by river to Santa Fé, on the Paraná, the chief depôt for external trade. Frézier (1712–14) writes that the ordinary route was from Santa Fé to Jujuy in the Argentine by wagon and thence to Potosí in Bolivia by mule-back. Chile, according to Juan and Ulloa (1740–44), was supplied direct from Buenos Aires, and passed supplies on to Peru.

The most vivid and detailed account of what had developed into a well-organised industry was given by the Robertsons in the first half of the nineteenth century. Then, the chief collecting regions, the *montes*, or woods where the ilex flourished, were near Villa Real, about one hundred and fifty miles up river from Asunción. The work of collecting was lucrative, but so arduous that it was usually performed by newcomers and men in debt. These concessionaires were financed or ' grub-staked ' by merchants of Asunción, who expected repayment in the form of *yerba*.

Each concessionaire hired twenty to fifty workers, and the difficult journey through untracked forest to the ilex groves (*yerbales*) ended when a promising locality was reached ; here camping-ground was prepared for a stay of six months or so, with huts for the personnel and corrals for the mules and oxen. The *tatacua*, a space some six feet square of hard-beaten earth, with a post at each corner, was made ready for the preliminary curing of the leaf, a simple process of scorching the masses of verdure over burning logs.

Nearby the *barbacua* was prepared, an arch of boughs supported on trestles ; upon this arch the ilex leaves, now readily separated from large twigs and boughs, were placed for the secondary drying. The fire built below the arch was carefully tended to prevent the leaves from burning, and to ensure complete drying ; and when the process was complete the *barbacua* and the ashes of the fire were removed, the ground swept and beaten smooth, and the dried ilex leaves placed on it, and pounded with wooden mallets.

The powdered or broken leaf was then packed tightly into sacks made from freshly flayed bulls' hides (*serones*), sewn up and left to dry. Each *seron* weighed 200 to 220 lbs. when dry. A similar process is employed to-day.

The origin of the practice of infusing the leaves of the ilex is very obscure. The earliest mention of the drink I have quoted above from Nicholás Durán (1626–27). By that time, as the extract shows, the beverage had spread far and wide through South America. But there is no account of its discovery. Pinelo, writing in 1636, refers to an author, Robles Cornejo, where he says a full account of the herb is given. Cornejo's work, *Examen de los Simples Medicinales*, dated 1617, must contain the first reference to the drink. But the book existed only in manuscript and, though mentioned in Cejador y Franca's *Historia de la Lengua y Literatura Castellaña*, has absolutely disappeared.

So far, evidence would seem to show that the drink was a native discovery, developed by the Jesuits ; but a study of the early history of the country

provides another aspect. The Rio de la Plata was discovered by Juan Diaz de Solis in 1516. In 1534 an expedition was sent from Spain under Pedro de Mendoza to make permanent occupation of the country to the north. With him sailed one Ulrich Schmidt, or Schmiedel, as he was called by the Spaniards, a Bavarian agent of merchants in Seville. He ascended the Paraná and Paraguay with the pioneer expeditions and made many journeys of exploration through the heart of the Guaraní country, finally making a cross-country journey of some hundred and thirty miles from the upper Paraná to São Vicente; after this he returned to Europe after an absence of nearly twenty years. His reminiscences are remarkable from several points of view, and perhaps especially for the accuracy of his memory and the almost incredible vileness of his orthography in dealing with Spanish and Indian words. His narrative is of great importance to anthropology, because it is the report of a pioneer and an observer. Whatever he may have forgotten, his mind is extraordinarily clear on the food question. He writes in detail what he had to drink and eat and where, day by day. Naturally, food was very important, and these European expeditions, living on the country, were often on the verge of starvation. For days they had to pass through unoccupied country, and their minds were naturally focussed on the food quest. Schmidt tells how the Carios make 'wine' of Mandepore (manioc) and of honey; the Mbaia and Payagua, of 'fenugreek'; the Guyacurú, of the algarroba bean. But in none of his copious food notes does he ever make mention in his twenty years' experience of the use of the ilex leaf, either chewed or infused.

During the period of Schmidt's residence in Paraguay, Cabeza de Vaca was sent to the country as Adelantado. From São Francisco, in the far south of Brazil, where he landed, he made a remarkable overland journey to the newly founded settlement of Asunción, passing through the heart of the country where the ilex grew naturally. In the course of his three years' residence he made several journeys northward. His narrative (1555) is full of details of considerable ethnographical importance and, though he pays less attention to local foodstuffs than Schmidt, the precarious nature of his supplies led him to record much useful information on this subject. Yet in his account there is no mention of the ilex.

Between 1569 and 1574 Nicolas Monardes published a work entitled *Las cosas que se traen de nuestras Indias occidentales*, translated into English in 1580 under the far more attractive title *Joyfull Newes of the New-found World*. He gives an extended and delightful description of the properties of coca, tobacco and many other American products, but there is no mention of *yerba maté*.

Diaz de Guzman (1612) gives a descriptive account of practically the whole region occupied by the Spanish east of the Andes in his *Historia Argentina* (Paraguay did not become a separate province until 1620), but there is no mention in his pages of the 'Herb of Paraguay.' Thus the first reference to the use of the ilex leaf does not occur in literature until more than ninety years after Schmidt entered the country, eighty-five years after Cabeza de Vaca passed through the forests which later became the principal source of supply, and more than half a century after

Monardes had published his series of monographs on the economic contribution made by the newly discovered Americas to the Old World. The lost MS. of Cornejo might supply the information as to the origin of the commercial use of the 'herb.' But the inference is, on the evidence, that the leaf was not in general use by the natives prior to the establishment of the Jesuit missions, except, perhaps, for chewing.

The native name of the dried leaf gives little help. In the Guaraní dialect the principal varieties were known as Caamini and Caaguazú (in Brazil, Congonha).

The tree itself was known as Caa, which simply means a tree, a generic term, and it is easy to produce parallels from other native dialects that no plant of importance is mentioned except by a specific name. The implication is that, as far as the natives were concerned, the ilex was merely a tree.

It has been suggested that the word Caa bears some relation to the Chinese C'ha, meaning tea in the Pekinese, Mandarin and Cantonese dialects. Tea was first brought to Europe by the Dutch in the early seventeenth century from Bantam, whither it had been imported by Chinese merchants from Amoy, where it was called Té. The Portuguese found it in Macao, under the name C'ha, a little later. The first mention of tea in Western literature is in Maffei's *Historica Indica*, published in 1558. It is not inconceivable that the Jesuits of the period, looking for a substitute for tea, by then introduced into southern Europe, also introduced the Chinese word, which was mis-pronounced by the natives.

The subsequent development of the *Yerbales*, or ilex plantations, is a matter of history. The economic importance of the leaf, combined with the fact that it grew in the less accessible regions (swampy mountain valleys), soon led to the inception of attempts to bring it under cultivation. Rodero gives the account of the first attempt.

Young trees were brought from Maracayu to the mission communities along the Paraná river, but did not flourish. Experiments in raising seedlings were also a failure. The eventual success is recorded by Dobrizhoffer (1749), who reports that the seed of the ilex is covered with a thick coating of gluten which prevents germination. In the wild state, this gluten is removed by passage through the bodies of certain birds, principally the South American pheasant (Jacu). This gluten was eventually removed by careful washing and the seed sown deep in ground drenched with water. The young seedlings were planted out in deep trenches under thatched shelters. Yet, even after these precautions, the cultivated plants never attained the size of those growing under natural conditions. However, the *Handbook of Paraguay* (1894) states that the Jesuit attempts were so successful that at Santiago (Paraguay) there once existed a grove of 20,000 trees. On the expulsion of the Jesuits these plantations disappeared, and only in recent years have successful *yerbales* been established in the Misiones territory of North-eastern Argentina.

The ilex tree remained without any name assigned by international botanists until the nineteenth century; and it was by a curious piece of bad luck that the famous French botanist, Dr. Bonpland, was prevented from having the honour of classifying *yerba maté*. Bonpland went, in

the year 1820, up-river from Buenos Aires to Paraguay, with the object of obtaining specimens of the plant; but Paraguay, always isolated, was under the dictatorship of that extraordinary individual José Gaspar Francia, whose policy put a fence round the little country. Bonpland was placed under a kind of arrest, detained for many years, and while he was still practically a prisoner of Francia's, *yerba maté* had been seen by Saint Hilaire in South Brazil, in the Curityba region, identified as a member of the ilex family, and named by him *Ilex paraguariensis*. Saint Hilaire afterwards changed the name to *Ilex maté*; but meanwhile, in 1824, A. B. Lambert, the distinguished English botanist, described the tree, illustrated it, and gave it the name *Ilex paraguayensis*, by which it is now usually known.

The subject with which I have been dealing may seem, at first sight, to be a little removed from the activities of the Section. But I would suggest that the study of Ethno-botany is of the highest importance. The rapid spread of stimulants, narcotics and food plants throughout the world has a direct bearing on culture-diffusion.

But trouble arises from the fact that valuable food plants spread so rapidly that their origin becomes obscured. Especially cereals. Maize, to give one instance, indigenous to America and unknown in the Old World before Columbus, became the staple food of half Africa within a century of the discovery, spreading from tribe to tribe, far beyond European exploration. In Europe it penetrated to the Levant, and became known in France as *blé de Turquie*. In Germany it was called *türkische Weisen*. In England it was called guinea corn, because it came to us from West Africa.

I suggest that there is a splendid opportunity for a young man, trained in botany, to undertake the revision of that fine work *The Origin of Cultivated Plants*, written by Alphonse de Candolle. The last edition of this was published in 1909, but the Preface, written in 1882, is a model of sympathetic guidance to those who follow. Much has been discovered since de Candolle's day, and a new edition is badly needed. It is in the hope that some of the younger men may take up the task that I have chosen this subject for my address.

Bibliography.

1535–53. Ulrich Schmidt (Schmiedel), *A True and Agreeable Description of some Indian Lands.* (Hakluyt Society, vol. lxxxj, *The Conquest of La Plata*, ed. by L. L. Dominguez, London, 1891.)

1541–44. Alvar Nuñez Cabeza de Vaca, *Commentaries*, in the same volume as the preceding.

1569–74. Nicolas Monardes, *Joyfull Newes out of the New-found World* (London, 1580); a translation by John Frampton of *Las cosas que se traen de nuestras Indias Occidentales.* (Seville, 1569–74.)

1612. Rui Diaz de Guzman, 'Historia Argentina, in P. de Angelis' *Collection de Obras y Documentos*, vol. i. (Buenos Aires, 1836.)

? 1617. Antonio de Robles Cornejo, *Examen le los simples Medicinales* (MS.)

1626–27. Nicolaus Durán, *Litterae Annuae Provinciae Paraquariae Societatis Jesu.* (Antwerp, 1636.)

1636. ANTONIO DE LEON PINELO, *Question Moral si el Chocolate quebranta el ayuno Eclesiastico.* (Madrid, 1636.)
1649–80. NICOLAUS DEL TECHO (DU TOIT), *Historia Provinciae Paraquariae Societatis Jesu.* (Liége, 1637.) (English translation in Churchill's *Collection of Voyages*, vol. iv. London, 1732.)
1692. ANTHONY SEPP, 'Account of a Voyage from Spain to Paraquaria.' (Churchill's *Collection of Voyages*, vol. iv. London, 1732.)
1711–14. FLORENTIN DE BOURGES (quoted by Bouchet) in *Lettres edifiantes et curieuses*, Tome viij. (Paris, 1781.)
1712–14. M. FRÉZIER, *Rélation du Voyage de la Mer du Sûd.* (Paris, 1732.)
1720. CAPTAIN BETAGH, 'A Voyage round the World. (London, 1728.) (Reprinted in Pinkerton's *Voyages*, vol. xiv.)
1729. VAT, in *Lettres edifiantes et curienses*, Tome ix. (Paris, 1781.)
C. 1734. GASPARD RODERO, 'Mémoire apologetique,' in *Lettres edifiantes et curieuses*, Tome ix. (Paris, 1781.)
1740–44. JORJE JUAN and ANTONIO DE ULLOA, *Voyage to South America.* Translated by J. Adams. (London, 1807.)
1740–46. JOHN BYRON, *Narrative.* (London, 1785.)
1749–67. MARTIN DOBRIZHOFFER, *Historia de Abiponibus.* (Vienna, 1783.) (English translation by Sara Coléridge. London, 1822.)
1757. F. XAVIER DE CHARLEVOIX, *Histoire du Paraguay.* (Paris, 1757.)
1772–76. COSMÉ BUENO, *El Conocimiento de los Tiempos.* (Lima, 1772–76.)
1781–1801. FELIX DE AZARA, *Voyages dans l'Amérique meridionale.* (Paris, 1809.)
1807. S. H. WILCOCKE, *History of the Vice-royalty of Buenos Aires.* (London, 1807.)
1811–30. J. P. and W. P. ROBERTSON, *Letters on Paraguay.* (London, 1838.)
1817. ROBERT SOUTHEY, *History of Brazil.* (London, 1817.)
1816–22. A. DE ST. HILAIRE, 'Aperçu d'un Voyage dans l'Intérieur du Brésil.' (*Mémoires du Mus. d'Hist. Nat.*, Tome ix. Paris, 1822.)
1817–20. ENDLICHER and MARTIUS, *Flora Braziliensis.* (Vienna, 1840–1906.)
1820–21. PETER SCHMIDTMEYER, *Travels into Chile.* (London, 1824.)
1824. A. B. LAMBERT, *A Description of the Genus Pinus.* (London, 1824.)
1842. SIR W. J. HOOKER, 'Some Account of the Paraguay Tea.' (*London Journal of Botany*, vol. i, 1842.)
1857. D. P. KIDDER and J. C. FLETCHER, *Brazil and the Brazilians.* (Philadelphia, 1857.)
1860. L. A. DEMERSAY, *Histoire physique, économique et politique du Paraguay.* (Paris, 1860.)
1878. T. P. BIGG-WITHER, *Pioneering in South Brazil.* (London, 1878.)
1879. A. T. DE ROCHEBRUNE, 'Récherches d'ethnographie botanique sur la flore des sépultures péruviennes d'Ancon. (*Actes Soc. Linnéenne de Bordeaux*, Tome xxxiij, 1879.)
1880. THOMAS CHRISTY, *New Commercial Plants.* (London, 1880.)
1886. H. SEMLER, *Die Tropische Agrikultur.* (Wismar, 1886.)
1894. *Handbook to Paraguay* (Bureau of the American Republics, Bulletin No. 54, 1892, revised to October 15, 1894), including Appendix B, Report of Consul Baker. (Washington, 1894.)
1901. R. *v.* FISCHER-TRUENFELD, 'Paraguaythee.' (*Deutsch Rundschau f. Geographie u. Statistik*, xxiij 15. Wien, 1901.)
1911. A. HALE, *Bulletin of the Panamerican Union*, vol. xxxij. (1911.)
1913. PABLO HERNANDEZ, *Organisación Social de las Doctrinas Guaranies.* (Barcelona, 1913.)

SECTION I.—PHYSIOLOGY.

NORMAL AND ABNORMAL COLOUR VISION

ADDRESS BY

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THE choice of a subject for a Presidential Address is a difficult matter. In this case, however, the following consideration seemed of importance in making the crucial choice.

Recently attention has been drawn to the number of accidents caused by mechanically propelled vehicles. The use of coloured signals may lead to difficulties for drivers with defective colour vision. History seems to be repeating itself with reference to the use of coloured lights. At one time it was claimed that no railway or marine disaster had been shown to be due to defective colour vision—which is not surprising, as the individuals concerned were never examined after the accident to see if they had normal colour vision.

One person with defective colour vision (hypochromat) has advised me not to say that coloured traffic lights cause any difficulty, as he can recognise them quite easily. On the other hand, I have heard that some drivers with defective colour vision do experience difficulty. Until the colour vision of persons who seem to disregard the coloured lights is tested, we do not know to what extent coloured lights constitute a difficulty to motor drivers with defective colour vision. In any case the remedy is simple, as a difference in shape of the coloured lights would be sufficient to prevent mistakes. It is true that the relative positions of the lights and other data may help in the recognition of the colour, so that the problem is not so serious as in the case of railway and marine services.

It is not my intention to give a detailed documentary description of recent work, as those interested will find references to many papers in some of the reviews of the subject.[1]

The aim of this address is to discuss three aspects of the Physiology of Colour Vision. The first aspect is the validity of the trichromatic hypothesis. There may not be many new things to be said, but a restatement of the arguments is useful as showing to what extent the

[1] H. Piéron, *Bull. Soc. d'Ophthal. de Paris*, p. 1 (1930). H. E. Roaf, *Physiol. Rev.*, **13**, p. 43 (1933).

hypothesis can be relied upon. The second aspect is the nature of the departures from normal colour vision of those with defective colour vision. The third aspect is a brief consideration of some theoretical views on the nature of colour-perceiving mechanisms.

Why is Colour Vision of importance in Physiology ?

All measurements depend upon perceptions ; many are concerned with visual perceptions, and some are based upon the perception of colour. Therefore the study of special sense physiology should be of interest to all branches of science. Colour is an attribute of vision ; therefore any views as to the perception of light by the eye must involve a consideration of the phenomena of colour. As colour sensation is interpreted in the brain, the study of colour vision involves not only the action of light on the retina, but also the transmission of impulses through the various layers of the retina and through the optic nerve, and the interpretation of the impulses in the brain. Some of these problems are common to other parts of the nervous system : therefore a thorough knowledge of colour vision may illuminate other sensory processes.

As the retina is merely an outgrowth from the brain, and the optic nerve a tract of the central nervous system, the function of the layers of the retina and of the optic nerve should correspond with other parts of the nervous system. Therefore, the distinctive problem in the physiology of colour vision is to discover how light affects the retina and produces nerve impulses. On the other hand, it is difficult to separate experimentally those activities due to stimulation of the retina from the activities of the various layers of the retina or the central nervous system.

Statement of the problem involved in the consideration of Colour Vision.

The real problem that one has to consider in special sense physiology is how the threshold of stimulation can be lowered for certain stimuli, but left high for others. The nature and action of the receptors determine what stimuli will most easily give rise to nerve impulses in certain nerve fibres. The number of varieties of receptors depends upon the data which must be presented to the cerebrum for the proper perception of sensory stimuli.

The first difficulty is to decide whether a single nerve fibre can convey impulses corresponding to more than one sensory datum. This problem was mentioned by Prof. Adrian in his address last year, and although the thesis cannot be definitely proved, the evidence seems to indicate that a single nerve fibre cannot convey more than one kind of impulse.[2] The velocity of transmission and other characteristics may vary from fibre to fibre, but it has not been shown that one fibre can convey different types of impulse.

If the above assumption is a legitimate one, we must endeavour to

[2] E. D. Adrian, *British Association Report*, p. 163 (1933).

reduce the sensory data to the lowest possible number, as the simplest mechanism is that requiring the fewest possible components.

All perceptions can be analysed into qualities of sensation—i.e. we can distinguish between sensations of light, sensations of sound, etc. These qualities can each be subdivided into different attributes of sensation, or subqualities. Some of these subqualities are common to all exteroceptive systems.

The subqualities of vision are perception of form or shape, perception of movement, recognition of differences in intensity, and discrimination of colour. Before we can attempt to distinguish the minimal data which must be presented to the cerebrum, an analysis of colour must be made.

What is meant in this address by Colour?

We can define colour as one of the psychological accompaniments of vision. The physicist defines radiation in terms of wave-lengths, but he should speak of colour only as a means of avoiding circumlocution. When we say 'red' light we use the term 'red' in quotation marks to stand for light which gives rise to the sensation of red in the normal person. In many cases no difficulty results from the use of such terms, but in a description such as this one we must be clear that there is a difference between the two uses of the words red, green, etc.—namely, the stimulating radiation and the sensation.

Colours are visible in the spectrum, and we can recognise certain colours, which seem unitary and distinct from all others, namely, red, yellow, green, and blue. There are, however, other unitary sensations which must be considered, namely, white and black: these cannot be produced by stimulation with any one region of the spectrum. These two sensations are sometimes described as belonging to the colourless sensations, but psychologically one cannot separate them from a discussion on colour.

Thus we find that certain colours are related to definite regions of the spectrum, but there are other sensations which do not correspond to any single group of wave-lengths: the latter are the purples, white, and black. All colours can be represented by fusion of lights from several regions of the spectrum, and the minimum number of regions is three. This physical relation is generally considered of paramount importance in the discussion of colour vision.

In 1802 Young postulated that there were three sensory mechanisms, because all colours could be reproduced by a combination of three regions of the spectrum.[3] There has always seemed some difficulty in reconciling this view with the psychological standpoint that there are six distinct kinds of visual colour sensation, namely, red, yellow, green, blue, white, and black. In the discussion of this problem some of these simple psychological effects can be shown to be built up from other sensory processes. The discussion of the sensation of yellow occupies an important place, but before we deal with the sensation of yellow it is simpler to consider the sensations of white and of black.

[3] T. Young, *Phil. Trans.*, **92**, p. 12 (1802).

Sensation of white cannot be produced by any single unitary physical stimulation. It requires the simultaneous action of light from more than one region of the spectrum. This seems to me a fundamental consideration, because if a simple sensation like white can be produced only by a heterogeneous stimulation, it is possible for a simple sensation like yellow to be the result of a heterogeneous stimulation. The sensation of white can be produced by stimulation by light from the whole of the spectrum, or from three or from two selected regions. There is no fixed standard of white. A white surface is one that reflects all visible wave-lengths well and equally. In order to define a ' white ' light a standard is taken of the radiation of a perfect radiator at 4800° K. or other specified temperature.[4] When a white sensation is produced by light from two regions of the spectrum, the separate sensations produced by these radiations are said to be complementary, and this phenomenon will be referred to later.

Black sensation cannot be produced by any combination of radiations. It is always the result of a *relative* deficiency of stimulation. A black surface is one that does not reflect any visible wave-length to an appreciable extent. To produce a black effect with spectral lights a brighter light must shine alongside them. Thus, a red produced by wave-length of about 6500 Å. looks brown when a bright yellow produced by wave-length of about 5900 Å. shines alongside of it.

The transition between white and black through grey depends upon the relative amount of illumination. There must, however, be the right mixture of wave-lengths, otherwise the grey will be tinted with the colour sensation produced by those wave-lengths which are in excess.

We are now in a position to consider the phenomenon of yellow. Yellow is a unitary sensation which can be produced by a single group of wave-lengths or by two groups, one each on the ' red ' and ' green ' sides of the ' yellow ' region. If we are to believe that three types of sensory mechanism are sufficient to account for colour vision, one of the four colours red, yellow, green, and blue must be due to a stimulation of at least two of the other ones. For several reasons, yellow has been chosen as the heterogeneous one.

To my mind there is no more difficulty in considering yellow as due to stimulation of two types of receptors than to consider white as due to stimulation of more than one type. Experimental evidence supports this view. Macdougall,[5] Rochat,[6] and others have shown that a ' red ' stimulus to one eye and a ' green ' to the other will give a sensation of yellow. This result is obtained even with lights from the spectrum. The fact has been demonstrated by Hecht,[7] but his method is not such a satisfactory proof as that obtained by other methods—e.g. a ' red ' glass over one eye and a ' green ' one over the other, or two definite wave-lengths of the spectrum each presented to one eye.

Central summation of this type shows that the sensation is built up in the nervous system beyond the optic chiasma, as neither eye need be

[4] W. D. Wright, *Proc. Roy. Soc.*, B, **115**, p. 49 (1934).
[5] W. Macdougall, *Mind. X.N.S.*, pp. 52, 210 and 347 (1901).
[6] G. F. Rochat, *Arch. néerl. de Physiol.*, **10**, p. 448 (1925).
[7] S. Hecht, *Proc. Nat. Acad. Sci. Wash.*, **14**, p. 237 (1928).

stimulated by the 'yellow' of the spectrum. The red and green sensations are lost, but their disappearance cannot be due to processes in the layers of the retina. As Macdougall points out, the alternative suggested by Hering that his four-dimensional system is cerebral rather than retinal deprives his hypothesis of its special value as a theory of colour vision. Hering's theory then becomes part of a general problem of how afferent stimuli are combined to produce perceptions, which is too complex a matter to be discussed here.[8]

As the unitary sensations yellow, white, and black can be built up from stimuli associated with other sensations, it is possible to reduce the number of data for colour perception to three.

The object of the above discussion is to show that there is no real objection to the trichromatic explanation of colour vision proposed by Thomas Young.

Colour Contrast.

In many observations on colour, contrast phenomena occur. These effects are always related to complementary colours. When, for example, one looks at a grey surface surrounded by a colour, the grey is tinted with the colour complementary to that used. This phenomenon is called simultaneous contrast or spatial induction. There does not seem to be any reasonable explanation of this effect except on a psychological basis.

To say that the inducing colour lowers the threshold of surrounding areas is purely hypothetical, and the evidence is in favour of the threshold being raised in surrounding areas. This effect of one area of the retina on another is part of the problem of adaptation to light.[9]

When a grey surface is viewed alongside a coloured surface, the light coming from the grey surface contains less of the dominant wave-length characteristic of the coloured surface than that coming from the coloured surface itself.

The grey surface is less coloured with the inducing colour, and as there is no fixed standard for white (or grey), it appears tinged with the complementary colour. Objectively it has a greater proportion of the complementary colour than the other surface.[10]

Successive contrast or temporal induction is produced by looking at a coloured surface and then at a grey one. The grey surface under appropriate conditions appears tinged with the colour complementary to the inducing one. This is easily explained by the process of adaptation whereby the frequency of impulses falls off rapidly during stimulation of the receptors. On looking at a neutral surface the impulses initiated in those end-organs which were stimulated by the inducing colour will be

[8] J. H. Parsons, *Introduction to the Theory of Perception*, Camb. Univ. Press (1927).

[9] H. E. Roaf, *Proc. Roy. Soc.*, B, **110**, p. 448 (1932). W. D. Stiles and B. H. Crawford, *Proc. Roy. Soc.*, B, **113**, p. 496 (1933). W. D. Wright, *Proc. Roy. Soc.*, B, **115**, p. 49 (1934).

[10] F. W. Edridge-Green, *Physiology of Vision* (G. Bell & Son), pp. 232–234 (1920).

fewer than those from the end-organs which were not previously stimulated; hence the more frequent impulses from the previously less stimulated receptors will produce the sensation of the colour complementary to the inducing one.

Defective Colour Vision.

Abnormal colour vision may be congenital or acquired. It is not my intention to discuss certain defects in colour vision due to disease—e.g. tobacco amblyopia.

Defective colour vision is a condition in which the persons affected make mistakes in matching colours. Any explanation of the nature of colour vision must be able to explain how certain colours are mistaken. The usual form of defective colour vision is congenital, and does not alter during life. This is what is generally understood when speaking of defective colour vision. The defect seems to consist in a decrease in the ability to distinguish 'red' from 'green,' and the subjects distinguish fewer colours than the normal (euchromat); hence they may be spoken of as hypochromats. It is very difficult to compare the sensations of such cases with those of a normal person, but they are frequently described as having blue-yellow vision. Another way of expressing the fact is to say that in the spectrum they distinguish blue from not blue, whereas the normal person subdivides the not blue into red and green. As 'yellow' occupies the region between 'red' and 'green,' the defect is most noticeable in the 'yellow' region of the spectrum, especially in the milder degrees of the defect.

Part of the evidence for these statements is that analysis of the mistakes made by hypochromats are all explained by a failure to distinguish red from green.[11] Further evidence is furnished by observations on colour discrimination.

By measuring the difference in wave-length necessary to cause a difference in colour, it is found that normal people have two main maxima of discrimination where a difference in colour is recognised for a minimal change in wave-length. These maxima of discrimination probably indicate where there is a most rapid change in the ratio of stimulation of two different types of receptor organs. The hypochromat shows only one maximum of discrimination, thus suggesting that he has only two types of receptor organs.

In extreme degrees of this defect the whole range of colours can be reproduced for these people by fusion of light from two regions of the spectrum.

The normal maxima are in the 'yellow' and 'blue-green' of the spectrum, whilst the hypochromat has only one maximum, that in the 'blue-green.' It appears as if the distinction on each side of the yellow had been diminished or lost: hence the failure to distinguish 'red' from 'green,' and the whole not blue portion of the spectrum appears more or less of one colour. The bearing of this on any theory of vision is that

[11] H. E. Roaf, *Quart. Journ. Exp. Physiol.*, **14**, p. 151 (1924). A. B. Follows, in the press (1934). H. E. Roaf, in the press (1934).

we must be able to explain how the distinction between red and green can disappear, yet without marked decrease in the visibility of any portion of the spectrum. The threshold for light is not necessarily altered, and it is possible for hypochromats to see clearly through a filter which allows only the red end of the spectrum to pass through. In fact a hypochromat who cannot see red geraniums amongst the green leaves can distinguish the flowers as light objects against a dark background when looking through a red glass filter.

Anomalous Trichromatism.

In 1881 Lord Rayleigh described a condition known as anomalous trichromatism, which is characterised by the fact that various people require different proportions of ‘ red ’ and ‘ green ’ to match a fixed ‘ yellow ’ but there seems to be no defect in the recognition of colours. This condition has been considered by some people to be the basis of a division of hypochromats into two groups, and that there are a series of cases ranging from normal vision to complete red-green confusion.[12]

Up to the present there has been no satisfactory explanation of the condition of anomalous trichromatism, and I am now investigating this condition. The explanation may be that the radiation corresponding to the sodium flame (5896 Å.) looks orange to some and greenish to others. If the fixed ‘ yellow ’ looks orange, the appearance suggests that the red sensation is relatively more stimulated by the ‘ yellow ’ light, and more ‘ red ’ would be required in the mixture to make the match, whilst if the fixed ‘ yellow ’ looks greenish, more ‘ green ’ would be required. It is not yet known whether a similar phenomenon is shown in matching a fixed ‘ blue-green ’ with a mixture of ‘ blue ’ and ‘ green.’ That some such explanation is possible is shown by Gothlin,[13] who finds that different people do not mark out the same region of the spectrum as yellow. The maxima of discrimination mentioned previously are also found to be at different wave-lengths for various individuals.[14]

The sensation of yellow seems to be a crucial problem, as it may be recognised at different wave-lengths of radiation, and if it is seen over a wide range of wave-lengths the subject has defective colour vision.

Means of Stimulation by Light.

Stimulation of the retina is due to a photochemical action. That is, the radiant energy is absorbed and converted into some other form of energy. Joly has ascribed the effect to a photoelectric process, meaning that electrons are given off as the result of the radiation. It is difficult to see in what way this differs from a photochemical action, as electronic changes in organic material accompany chemical change. One cannot compare

[12] A. Guttmann, *Zeit. f. Psychol. d. Zinnesorgane*, Abt. 2, **42**, pp. 24 and 250 (1908) ; *ibid.*, Abt. 2, **43**, pp. 146, 199 and 255 (1909).

[13] G. Fr. Gothlin, *Journ. Physiol.*, **57**, p. 181 (1923).

[14] O. Steindler, *Sitzungsber. d. Akad. Wiss. Wien*, **115**, 2a, p. 39 (1906). H. Laurens and F. W. Hamilton, *Amer. Journ. Physiol.*, **65**, p. 547 (1923).

these changes with those produced in photoelectric cells. Furthermore, it is known that there is a chemical substance in the retina which is bleached by light. It would be a remarkable circumstance if this photochemical change were entirely divorced from the function of vision. Hecht has published a series of papers on the photochemical action of light on living organisms, and it has been shown that the data for dark adaptation are best explained on the basis of a bimolecular chemical change. The analytical factors in sensation are generally considered to be specialised receptor organs which receive the stimuli and cause nerve impulses. These receptors act by having a low threshold to some manifestations of energy while maintaining a high threshold to others. It is for this reason that receptors are of such importance in the physiology of the nervous system.

Theories of Colour Vision.

If it is legitimate to regard all colour perceptions as being synthesised from three sensory mechanisms, we can return to the consideration of visual perceptions (p. 170.)

Perceptions of form may be regarded as related to the optical patterns produced in both uniocular and binocular vision ; therefore they are related to the anatomical connections between areas of the retina and of the cerebrum.

Perceptions of movement depend upon the presentation of successive patterns, such, for example, as shown by the cinematograph.

Recognition of intensity differences is ascribed to the frequency with which impulses reach the central nervous system.[15] Therefore we have to consider how the three subqualities underlying colour vision can be conveyed by the optic nerves. If we could prove that different types of nerve impulse could pass up the same nerve, we could say that a single nerve fibre could serve for all colour perceptions, but if we must limit each nerve fibre to one type of impulse, then we must look for separate nerve fibres for each of the three colour sensation processes. In other words, of the six properties of vision we can relate three of them—form, movement, and intensity—to anatomical, temporal, and frequency relations respectively. The other three, namely colours, must be related to different groups of nerve fibres. It is possible to imagine frequency relations giving rise to colour sensations, but we would then have to abandon the experimental relation between frequency and intensity.

The maximum frequency at which nerve impulses can pass up a nerve fibre is of the order 400 per second, whilst the frequency of light waves is from 400 to 750 billions per second. It seems difficult to imagine a relationship between such disproportionate frequencies.

The relation between receptor organs in the retina and nerve fibres in the optic nerve is complicated by the synapses in the layers of the retina (Granit has been investigating these problems[16]). If vision depends

[15] E. D. Adrian, *British Association Report*, p. 163 (1933).
[16] R. Granit, *Arch. of Ophthal.*, **6**, p. 104 (1931).

upon the presence of three types of receptors, it is difficult to see how the nerve fibres corresponding to the different sensations can be reduced to less than three groups, nor can one imagine how fewer than three types of receptors can give rise to three groups of nerve impulses. This is a general problem as to what extent simplification or complexity can be introduced between receptor organs and the interpreting mechanism in the brain. It seems to me that the trichromatic hypothesis implies, as stated by Young, the presence of three types of receptors linked with three groups of nerve fibres in the optic nerves.

The tentative conclusion is that, in order to explain the phenomena of colour vision, it is necessary to have three groups of nerve fibres passing to the brain—one group giving rise to sensation A, a second to sensation B, and a third to sensation C. We must discover what wave-lengths stimulate A, B, and C respectively, what sensations are produced by stimulation of one of these alone, and what is the effect of stimulating more than one of these, either to the same degree for each or to different ratios of response. Stimulation of the receptors may correspond to definite wave-length groups, but there may be a certain amount of rearrangement in the retinal synapses. It does not seem probable that the number of types of receptors or groups of nerve fibres can be reduced below three if frequency of the impulses is to be related to intensity of stimulation and if only one kind of impulse can pass up each fibre. It is like the solution of simultaneous equations: the number of equations must be at least equal to the number of unknowns to be found. That seems to be the essence of the trichromatic hypothesis as suggested by Young.

Helmholtz introduced the view that the differentiation is due to the presence of three photo-active substances which are acted on by the long, medium, and short wave-lengths of the visible spectrum respectively. The range of radiation which affects these three substances overlaps so that, for example, some rays affect all three of these substances. Up to the present there is no definite evidence for the presence of three photo-active substances, only one photo-active substance, rhodopsin or visual purple, has been found. Apart from this fact the view of three photochemical substances such as postulated by Helmholtz does not agree with the experimental evidence. For instance, in order to explain hypochromatism, it is not assumed that one photo-active substance is absent but that the range of activity has shifted so that the one substance is activated by the range which was formerly active on the two separate substances. It does not seem likely that such a chemical transformation would occur.

Hecht has attempted to modify the Helmholtz view by assuming the presence of three substances activated by practically the same range of radiant energy. The dissimilarities in Hecht's curves seem to me to be too small to explain the differences in colour sensations. Such views as those of Hering are untenable so long as we cling to the idea that a single nerve fibre can conduct only one type of impulse. Further, the sensation of yellow can be produced by the fusion of impulses from the two eyes: hence it is not due to the neutralisation of 'red' and 'green' in the

retina with a residual yellow effect due to both these ranges of radiation stimulating a yellow sensation-producing mechanism. Burridge's statement that there is an increase or decrease in rhythmical activity does not indicate how colour sensations are produced.

Edridge-Green describes a theory which is quite different from all others. He says that the rods do not cause visual sensations, their only activity being to produce visual purple. Visual purple is passed into solution and, when decomposed by light, acts upon and produces stimulation of the cones. He seems to regard each cone and each nerve fibre as capable of giving rise to a number of different colour sensations ; this suggestion requires a modification of the view that a single nerve fibre can conduct only one type of impulse.

Another suggestion is that put forward by Schultz (1866),[17] namely, that there is one photochemical substance but different coloured filters to distinguish the various regions of the visible spectrum. Such filters have been found in amphibia, reptiles, birds and marsupials, but have not been found in other mammals. The coloured filters in the birds' retinæ would explain the type of colour vision found in man. For instance, by reducing the intensity of red pigment in the red filters the various degrees of hypochromatic vision would be produced, but in a single human eye examined by me no such filters could be seen.

My own work leads me to suppose that the types of receptors which are stimulated by visible radiation are as follow :—

The first type of receptor is one which is stimulated by all parts of the visible spectrum and gives rise to a sensation of violet [18] when stimulated strongly by itself.[19]

The evidence for the first part of the above statement is the same as that which caused Hering to speak of a white-black substance and von Kries to describe a bluish-white sensation as due to stimulation of the receptors for achromatic scotopic vision : these usually being regarded as the rods.

The evidence for the second part of the above statement is first of all that a narrow beam of any wave-length when shining slightly eccentrically gives rise to a violet sensation. This has been called secondary excitation, implying that the sensation is due to stimulation of receptors by nerve impulses passing along fibres of the optic nerve. It is unlikely that such stimulation would occur, and if so, why should the sensation produced be

[17] M. Schultz, *Arch. f. Mikr. Anat.*, **2**, p. 255 (1866).

[18] It is with some hesitation that one states that violet is due to stimulation of a single receptor, as psychologically it suggests a mixture of blue with a little red. If violet is the sensation corresponding to stimulation of one type of receptor, we must regard the unitary sensation of blue as due to stimulation of the receptors for green and violet. It may be that blue is the sensation due to stimulation of the single receptor, and that violet is the result of stimulation of the receptors which give rise to blue and to red sensations. This matter must be left in abeyance, but the use of the term ' violet receptor ' is to be understood to mean either the receptor for violet or blue, owing to the fact that fatigue to ' red ' causes violet to appear more blue. Wright believes that the single receptor gives rise to a sensation of blue.

[19] W. O. Sivén, *Shand. Arch. f. Physiol.*, **17**, p. 306 (1905).

violet? On the whole, it seems simpler to interpret it as stimulation of rods by any wave-length. Furthermore, diseases involving the rods lead to night blindness or raising the threshold of achromatic scotopic vision. If this threshold is sufficiently raised then there is loss of vision for violet, so that the distinction between green and blue is lost.[20] This defect is a true violet blindness, because it is accompanied by a raised threshold for the short wave-length end of the spectrum. Finally, adaptation to light conditions is accompanied by a special raising of the threshold to the short wave-length end of the spectrum. Therefore, although the point is not proved, there is much evidence in favour of violet vision being a function of the rods.

The second type of receptor is one which is concerned with the not blue aspect of vision of the hypochromat. These may be cones of which there need be only one variety for the hypochromat.

The third type of receptor would be functional in normal vision, and it seems as if this second variety of cone were one that distinguishes red from not red, and according to the activity of this variety the stages between normal vision and complete red-green confusion can be bridged.

Therefore, normal vision may be due to a receptor which gives rise to a red sensation, one which gives rise to a blue sensation and one which gives rise to a not blue, not red sensation which, of course, corresponds to green sensation. The actual wave-lengths of radiation that stimulate the several receptors are not known. The real difference between various hypotheses is the extent and region of the spectrum which stimulates the end-organs.

In the Young-Helmholtz hypothesis the type of receptor responsible for the sensation of red is stimulated by almost the whole of the spectrum, but most strongly by the long wave-length end. The receptors for green are stimulated by almost the whole spectrum, but most strongly by the mid-region. And those for blue are stimulated by a large extent of the spectrum, but most strongly by the short wave-length end.

'Red' light of longer wave-length than 6200 Å. is supposed to stimulate the red receptor only, whilst shorter wave-lengths will stimulate the red receptor to decreasing degrees, but the other receptors to increasing extent, hence the change of colour with wave-length.

Relation of Wave-length Differences to Colour Discrimination.

The change of colour is probably most noticeable when the change in ratio of stimulation of the receptors is most marked—e.g. yellow sensation might correspond to a sudden decrease in frequency of impulses from the receptors for red, a sudden increase in impulses from the receptors for green, or a rapid decrease of the former and rapid increase of the latter. This assumption is one reason for the great interest in the maxima of discrimination in the spectrum.

[20] H. Köllner, *Die Störungen des Farbensinnes* (S. Karger, Berlin, 1912).

Interpretation of the relations between receptors and incident light is not yet attained. Sensation curves merely express the results of matching regions of the spectrum with three groups of wave-lengths. As Wright remarks,[21] ' The physiological mechanism by which such an effect could be produced cannot be visualised very readily, but it would apparently necessitate the assumption that all three fundamental responses have some quality in common, so that one response could produce a subtractive effect on another. This quality must probably be in the nature of an inherent " whiteness," and it is on an assumption of this sort that saturation differences might be explained.'

This view has much in common with the belief of Hering and von Kries that there is an underlying white sensation to all stimuli.

It is possible that monochromatic regions of the spectrum may stimulate all three types of receptors to constant ratios—e.g. the extreme ' red ' end of the spectrum may stimulate all three types to equal degrees or any ratio such as 3 : 2 : 1. Therefore, the monochromatic ' red ' at the end of the spectrum may correspond to stimulation of the three types of receptors, and not only of one, as represented in Wright's curve. A high degree of discrimination, as in the ' yellow,' would correspond to a rapid change in the ratio of stimulation. Therefore, (*a*) the red sensation is rapidly falling off, (*b*) the green sensation is rapidly increasing, or (*c*) the red is decreasing and green increasing rapidly about 5800 Å. Similarly a change in the ratio of stimulation is taking place rapidly about 4900 Å.

It is difficult to know how to test these assumptions. The phenomena of binocular rivalry, etc., indicate that nerve impulses may be suppressed before they produce consciousness : hence sensations may not always correspond to the algebraical sum of nerve impulses—e.g. an object seems darker when a semi-transparent screen is placed in front of one eye than if the one eye is entirely obscured.

Conditions necessary for the Investigation of the Specific Stimuli for Visual Receptors.

For the purpose of finding out what range of wave-lengths is effective on the different receptors, weak stimuli must be employed. The eye must be in a condition of dark adaptation, because any other state is accompanied by stimuli which make the results more difficult to interpret. ' White ' light should never be used, as it stimulates all receptors ; therefore specific relations between receptors and stimulus are upset.

With stronger stimuli a wider range of radiation will become effective in stimulating the end-organs ; in fact, with strong illumination it is known that the purity of the sensation diminishes, thus showing that weak illumination is better for the purpose of differentiating the relation of receptors to different wave-lengths of radiation.

The effect of one group of wave-lengths on the sensitivity of the same

[21] W. D. Wright, *Proc. Roy. Soc.*, B, **115**, pp. 69–70 (1934).

area of the retina to another group, is probably the only method of comparing the stimulating actions of these groups on the same receptors. If different receptors are acted upon, one light should not affect the sensitivity to another, but if the same receptors are concerned, then interference will take place according to the Weber-Fechner relationship.

Experiments of the above nature suggest that long wave-lengths of visible radiation stimulate all receptors to an appreciable degree, whilst the shorter ones act mainly on one only.

As a result of my own experiments I am led to believe that the ranges of wave-length which stimulate the various receptors correspond to the effects to be expected from the coloured globules found in the birds' retinæ. No such colour filters have been found in the eyes of mammals higher than the group of marsupials. It may be that photo-active substances are the means of selection.

The three types of receptors would be : (1) Those corresponding to the red globules which would be stimulated by the long wave-length end of the spectrum, with a marked falling off in effect about 5800 Å. As no filter is absolutely opaque, it is probable, especially with bright lights, that some stimulation of these occurs by wave-lengths to the extreme short wave-length end of the spectrum. These receptors would be absent or the pigment in the filter reduced in the various degrees of hypochromatism. (2) Those corresponding to the yellow globules which would be stimulated by long and intermediate wave-lengths, with a marked falling off in effect about 4900 Å. Some stimulation might also be produced by shorter wave-lengths. (3) Those corresponding to the pale greenish globules which could be stimulated by the whole of the visible spectrum. 'Red' light would thus stimulate all three receptors. 'Green' light would stimulate mainly two. 'Violet' light would stimulate mainly one.

Summary.

Colour vision is probably dependent upon three types of receptor organs. In some persons the activity of one of these types is reduced or absent, giving rise to varying degrees of defective colour vision.

Discrimination curves suggest that the change in ratio of stimulation occurs rapidly at wave-lengths about 5800 Å. and 4900 Å. Hypochromats do not possess the maximum near 5800 Å. ; hence their dichromatic vision depends upon two types of receptors with marked change in ratio of stimulation by wave-lengths about 4900 Å.

The normal person differs, therefore, from the hypochromat in that the former is better able to distinguish wave-lengths of radiation longer than 5800 Å. from shorter ones. The defect does not appear to be a mere absence of one type of receptor leaving a portion of the spectrum unrepresented, but it seems as if the red discrimination of the euchromat were superimposed on a background of something else. In the absence of discrimination of 'red' the background might be classed as yellow, but

when discrimination of ' red ' is present the sensation of yellow is aroused by a region of the spectrum which separates that giving a red sensation from that which gives another colour, namely, green.

The deficiency is always characterised by a spreading out of the portion of the spectrum which gives rise to a sensation of yellow until, in severe cases, the whole of the spectrum from 4900 Å. to the extreme ' red ' end is distinguished only by characters such as brightness or decrease in blueness.

SECTION J.—PSYCHOLOGY.

PSYCHOLOGY AND SOCIAL PROBLEMS

ADDRESS BY

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Social problems are partly material and partly mental. Every society consists of interdependent personalities whose harmonious co-operation is necessary for the general well-being, and the really serious problems of life concern this co-operation. Very great progress has been made in the solution of the material problems: the physical and biological sciences have given increased control over material resources; the energy values of foods have been determined, the amounts required for different kinds of work have been calculated, and preventive and remedial measures have been devised by medical science which are improving national health and lengthening life.

Very much less attention has been given to the study of the mental aspects of social welfare, perhaps because every man finds it difficult to persuade himself that his conduct and thought can be studied as physical and biological phenomena are studied, resenting the suggestion that anyone but himself can know what he is going to do or what he is able to do, and yet with a strange inconsistency not hesitating to claim for himself such knowledge regarding others, or perhaps it is because the conditions that affect human thought and behaviour are so extremely complex that they make the understanding of a chemical reaction a trivial matter as compared with that of a bit of human behaviour. Nevertheless, for a proper understanding of the numerous problems that arise from life in a community, such as those of supply and demand, labour and capital, law and order, hygiene, housing, transport, education, the conflict of traditions and ideals, and local and international rivalries, the study of mind is just as important as is that of matter. The solutions to these problems are to be found ultimately in the forces that move men to action, in their inherited tendencies, in their acquired habits, in the mentality of the groups to which they belong, and in their relationships to those groups.

Most men with any experience of the world know this, but it rarely occurs to them that these matters are amenable to scientific treatment: they rely on their own intuitions, seldom doubting their truth, preferring persuasion to proof. If opinion is to give place to knowledge, scientific method is just as necessary here as it is in chemistry, physics or biology, for it is just a deliberate effort to get a clear understanding of things by

making systematic observations under conditions which others can repeat, by inventing explanations, and by testing these explanations thoroughly and impersonally.

An appreciation of this need for objectivity was doubtless in Fechner's mind when he dreamed of measuring sensory experiences and making psychology as mathematical as the physical sciences: it certainly underlies the activities of the experimental and statistical psychologists. Fechner's hopes have not been realised. Psychology has had to develop methods suitable to the solution of its own problems, and these have not been the classical methods of the physical sciences: they are more like those of the biological sciences. They are essentially systematic methods of describing and analysing the experiences and bodily activities of representative samples of the population under specified conditions. This is the logic of psychological inquiry: it is a slow, laborious business, not nearly so exhilarating nor so impressive as the invention of sweeping generalisations supported only by rhetoric and casual observation; but it is necessary, and, in the end, satisfying.

Though the need for objectivity is recognised in the experimental laboratory, where information is laboriously collected and analysed, and where theories are thoroughly tested, it has not been so clearly recognised in the treatment of the psychological aspects of social problems. The social psychologist seems to be drawn to those branches of his subject which are the most obscure and the least amenable to objective co-operative testing and to those methods of inquiry which are the least exact: he maintains, for example, that the department of psychology that is of first importance for the social sciences is that which deals with instinctive impulses, and for his knowledge of these impulses he relies largely on casual observation. There has been much speculation regarding the number and nature of the innate human tendencies and their operation in social life, and there are fascinating theories regarding the ways in which individual personal experience affects behaviour. Unfortunately, much of this lacks the precision and objectivity which science demands; it is in the old philosophical tradition, being characterised by wide generalisations based on casual observation, subtle analyses and fine distinctions that are often merely verbal; it is not based on that controlled and repeatable observation which makes science. It is none the less useful, for it provides working hypotheses and it is perhaps inevitable; but it has to be tested: so long as its main support is general impression and opinion, no matter how respectable, it is not science.

Much of the text-book psychology of behaviour falls into this category. Casual observation suggests that there are forms of behaviour which are common to all the members of a species, unlearned and grounded in inherited structure and disposition, and, as McDougall, Drever, Bartlett and others have shown so clearly, such innate dispositions explain much of human behaviour; but we still lack methods of assessing the strengths of these tendencies: few people doubt that there is an innate tendency to remove more or less violently obstacles to one's activities and that it varies in strength from one person to another and from one race to another, but until satisfactory objective methods of assessing it have been devised,

comparisons between individuals and between peoples as to the strengths of these tendencies will remain difficult and unreliable.

Such methods will probably be devised in the course of time: as regards the temperamental traits, which are believed to be important for social life, some crude beginnings have already been made with the so-called rating scales. Certain qualities of mind, such as impulsiveness, steadiness, and cheerfulness, are selected and each person under investigation is rated in respect of each trait on, say, a five-point scale, that is, he is put into the first, second, third, fourth, or fifth class, the classes being chosen so that in a representative sample of the population the numbers in them will form a distribution that is approximately normal. The success of this method obviously depends on the sagacity and experience of the examiner: it gives a partially controlled subjective estimate which is probably accurate enough for some purposes and very much better than a haphazard uncontrolled judgment, but is somewhat unreliable when estimates by different people are pooled or compared, as anyone can discover for himself by getting estimates made in this way by different observers on the same group of people. The method is promising: it would be completely successful if the estimates were based on adequate descriptions of systematic direct observations of behaviour.

While it is true that racial inborn tendencies to activity, such as aggressiveness and curiosity, are of great social importance, it is equally true, and perhaps more important for practical life, that these tendencies, as they appear in man, are ill-defined as regards both the stimuli which excite them and the actions in which they issue, and that they are easily directed: this is important for social life because it is an essential condition of educability. It is in this respect that human innate tendencies differ from those of the lower animals. After all, a human community *is* different from a mere animal herd; even an undisciplined, brutal and stupid mob is not quite so stupid as a herd of animals. With rare exceptions all the members of an animal herd appear to feel and act in the same way: they hunt or browse together, apparently enjoying one another's society and protection, but there appears to be very little co-operation between them: for this there is needed diversity of ability as well as a common purpose, and it is just this which distinguishes a human group from most non-human groups, with the possible exception of such groups as those of ants and bees, which, however, are physiologically so far removed from us that it is futile to attempt to compare their mentality with our own. A typical human group is not the squad on the parade ground where every man is expected to make the same movement at exactly the same time, but rather an army in action where each man's work is different from that of his neighbour, but all are interdependent and working for a common purpose. A human community, in fact, implies variety of ability and effort, organisation, and an appreciation, more or less clear, of relationship to the group, and its success depends very largely on its intelligent use of its resources.

Social problems can be approached either from the point of view of the individual or from that of the group to which he belongs. Neither approach can be consistently maintained to the exclusion of the other, for the

problems of the individual are the problems of society and *vice versa* : a man is not independent of his fellows ; his social environment is part of himself ; his thoughts, feelings and desires vary with his environment ; he is socially a chameleon, and any account of him which fails to consider his environment is as distorted as is an account of society itself which fails to consider the variety of aptitudes, motives, knowledge, manners and customs of its members. A social group is a complex structure which contains within itself other groups and sub-groups, professional, economic, linguistic, etc., whose harmonious co-operation is necessary for the welfare of the whole. The big social problem is the dual one of fitting the individual into the group and fitting the group to the individual. This is essentially an educational problem, one for education in the widest sense of the word ; it concerns the home, the school, the university, the press, and the broadcasting and other publicity agencies. Its solution demands some knowledge of the natural endowment of the individual, his impulses and intellectual capacities, and of methods of making the most of them ; and this in its turn implies the need for and the use of methods of assessing human endowment and achievement.

I wish to consider especially the scientific assessment of natural capacity and some of the problems connected with it, therefore, it is necessary to keep clearly in mind the distinction between ability and capacity. Ability is actual, capacity is potential. Ability is measured by what can be done here and now ; capacity can usually be estimated by what can be done after a course of training. Knowledge and skill at games are forms of ability ; they depend on certain natural capacities and on upbringing. All examinations are tests of ability.

The satisfactory measurement of ability is always difficult on account of the adaptability of the human organism. The measurement of the efficiency of an engine is by comparison a very trivial affair. Even the best of examinations gives a somewhat blurred estimate of human mental ability.

The measurement of ability is difficult enough, but the estimation of the parts played by native capacity and upbringing respectively in determining such ability is very much more so. Innate qualities do not exist *in vacuo* : they exist with reference to certain external conditions and they must be diagnosed and measured in relation to these conditions. Every test is directly a test of ability, and can be a test of capacity only indirectly. Where training has no effect on the expression of a capacity, then a test of ability is a test of capacity ; but few, if any, capacities are unaffected by training. If opportunities and incentives are so widely scattered that they are available for everybody, or if similar training has been given to all, then differences in performance indicate differences in capacity ; but where the essential training and environmental conditions vary, inferences regarding capacity can be made with much less certainty. It is difficult to convince oneself regarding the uniformity of external conditions and easy to blunder : for example, it is sometimes supposed that mental differences between children of the same parents are due solely to genetic differences, but some of them are certainly due to variations in the family environment : the health and age of the mother are not the same at the birth of each child

(unless they be twins) ; families move from easy to difficult circumstances and *vice versa* ; parents become more experienced, or more indulgent, in the management of their children ; school-fellows vary ; and the children themselves vary in their relationships to one another and to the rest of the world. The conditions of the experimental chemical laboratory cannot be exactly reproduced in the study of human and social phenomena ; we have to be content with approximations to these conditions.

It is necessary to stress these considerations of method, for psychologists have hitherto been more concerned to distinguish and measure different kinds of ability which *seem* to be dependent on native capacity than to prove their innate basis. An example may make this clear. It is a common belief that people differ in respect of mechanical ability, that some have little difficulty in understanding the working of a motor car, a dynamo, a clock or other piece of mechanism, and that others find these things unintelligible ; it is also commonly believed that these differences are due to differences in natural capacity. Now, the first thing that must be done is to find whether there is actually a positive correlation between ability to solve one kind of mechanical problem and ability to solve other kinds, for until such a correlation has been established, it is futile to talk about mechanical ability. This is the kind of problem on which much effort has been spent, especially in this country : but after a correlation has been established, it is still necessary to find to what extent this ability is the expression of a specific inborn capacity. This more difficult problem is usually attacked by using test situations so novel that there is little probability of one examinee having any advantage over another through familiarity with the situation, or by using problems such as occur so often that it can be presumed that inability to solve them is due ultimately to innate incapacity. In practice, the difficulty, once it has been recognised, is probably not so great as may appear, for the opportunities of and the need for exercising most of one's native capacities are in fact numerous ; a person who fails to pass a properly designed and properly conducted test of colour blindness is almost certainly colour-blind.

All kinds of capacities are being investigated with varying success, and it may be possible some day to evaluate mental characters with some approximation to the accuracy with which physical characters can be assessed. What is needed is more extensive and more co-operative work. Most progress has been made in the evaluation of intellect by the so-called intelligence tests, largely under the pressure of educational needs.

Intelligence tests, as developed by Binet, were simply tests of educability, methods of picking out those children who are incapable of profiting from the education provided in the ordinary primary school. They have done more than this, for they have provided a method of distinguishing all degrees of general capacity. In principle they are just a refinement of a very common method of estimating native brightness. Binet put to children questions about topics which were likely to come within their everyday experience ; he found what average children of different ages could do and was able to arrange his questions in a scale of increasing difficulty ; then he assumed that those who picked up the necessary information or acquired the necessary skill or showed the necessary

intellectual grasp of a problem at an earlier age than the average child were bright or intelligent, and that those who were slow in doing so were dull ; and subsequent inquiry has shown that his assumption was well grounded. The danger here lies in variations of opportunity and training. Obviously, a child who has not had the opportunity of using the current coinage, or of buying and selling (or playing at buying and selling), or of learning to read and write, is at a disadvantage when he is put through certain of the Binet tests. This danger, however, is not so serious as it appears at first sight, for the social environment of children living in civilised communities differs very little in so far as it affects the results of the tests, and most of the tests have been chosen so as to minimise the influence of the environmental factor. These tests have been analysed and improved, and Spearman claims to have shown that they measure a central common factor which is intellectual in nature and which, to be non-committal and to avoid the ambiguities of everyday speech, he calls, not intelligence, but ' g.'

Mental tests have been used so extensively and in connection with so many problems that they have yielded information of social significance. They have been been applied more or less carefully, and in forms more or less satisfactory, to children of all ages, races and grades of society, and the results obtained raise some hope of getting reliable information regarding the distribution of intellect in the population as a whole and in the various professional, social and economic strata, and regarding its connection with fertility, disease, environment, and other conditions : they suggest too that at last we may have here a method of getting reliable information which will throw light on the puzzling problems of mental inheritance.

Repeated application of these tests to the same children suggests that mental development, as measured by the tests, proceeds along lines analogous to those of physical development and that it reaches its maturity about the age of adolescence, as do stature and other physical characters. The *rate* of development is expressed by the ratio of the level reached by the individual to that reached by the average of his age—for example, a boy of age ten years who has reached only the level of the average nine-year-old is said to have an intelligence-ratio (mental-ratio or intelligence-quotient) of nine-tenths or 90 per cent. This figure seems to measure some innate capacity or capacities, for, though it varies from one person to another, yet it remains fairly constant for each individual and appears to be little affected by external circumstances. Even serious and long-continued spells of illness appear to affect it very little : it is only ailments producing progressive deterioration of the central nervous system, especially of the brain, such as encephalitis lethargica and some forms of epilepsy, that reduce it. Absence from school may interfere with a child's education and so promote social inefficiency without affecting his intelligence-ratio.

Changes in social and physical environment have very little effect in modifying this ratio unless they be very great. Residence in an institution does not appear to make the ratios more alike than they were on admission, and children who have never seen their parents, but have been reared in the same homes, show the same differences of intellect as do their

parents. It is very hard to find the necessary data to decide this question of the effect of environment. In Glasgow about 300 children were tested at the time of their removal from slum houses to a rehousing area, and again about eighteen months later. It had been intended to allow an interval of two or three years to elapse between the examinations, but so many of the children—about 20 per cent.—left their new homes, that the interval had to be shortened. The ages of the children varied from five to nine years, an age at which they might be expected to react quickly to the new and improved environment. At the second test they did on the whole show a just appreciable improvement, their average ratio was raised from 90·6 to 92·1. A control group that did not move from their slum homes showed no such improvement. The result of this investigation is cheering for those who are trying to improve the external amenities of life ; but the improvement is so small that it suggests that any improvement in the social virtues that is to attend the initiation of social welfare schemes may have to rely on the formation of new habits of thought, feeling and action, habits that will have to be learned, rather than on any improvement in intelligence.

Here, in the interest of scientific accuracy, a word of caution is necessary. While the constancy of the intelligence-ratio raises a presumption that this ratio is determined by genetic constitution, it may, however, to some extent be partly determined by other conditions, ante-natal, natal, or post-natal : birth accidents are certainly responsible for some cases of dullness and defect. There are, however, several considerations which suggest that in most cases the ratio does measure something that is innate, for example, this theory gives the readiest explanation of the fact that the correlation between the ratios of identical twins is higher than that between fraternal twins.

As might have been expected, the average intelligence of the children of men engaged in professional and skilled occupations is higher than that of the children of unskilled workers ; but more interesting and more significant for social problems is the fact that the variability within the different occupations is so great that there is much overlapping, in other words, high-grade intellect is not the exclusive property of any social class or professional grade. When more extensive inquiries have been made, it should be possible to estimate with fair accuracy the actual distribution of intellect in the different social and professional groups.

Perhaps more important still is the information regarding the distribution of intellect through the whole population. Various estimates have been made, but the most interesting for Scotsmen is one based on an investigation conducted in June 1932, by the Scottish Council for Research in Education with the assistance of education officers, teachers and others, in which a group test was given to practically the whole of the school population in Scotland born in the year 1921 and so of age $10\frac{1}{2}$ to $11\frac{1}{2}$ years, 87,498 in all.

A group test such as had to be used in this inquiry suffers from certain obvious disadvantages, the chief of which is that those who are tested must be able to read with understanding, and any weakness in this direction must affect their replies, but, as all parents are by law compelled to

make provision for the education of their children at age five, and most children begin to go to school at or about that age, any serious backwardness in this direction probably indicates some intellectual deficiency. If we assume that the average child can read sufficiently well at age nine, then this test, so far as the reading difficulty goes, was suitable for about 90 per cent. of the age-group that was examined. Another difficulty arises from the fact that one set of questions must be given to suit all levels of mental development from mental age nine upwards. A few of outstanding ability may not have taken the test, others may not have been examined fully enough to show all their ability, and none of those so markedly defective as to be certified for institutional care were examined : the findings regarding those at the extreme ends of the intellectual scale are, therefore, somewhat uncertain. Still, the general significance of the inquiry is quite clear.

The average agreed with previous estimates, but the dispersion proved to be greater than had previously been supposed—in other words, there were more who were dull and more who were bright : about half the population examined had mental ratios between 89 and 111 (instead of between 91 and 99, as was previously supposed), and it was estimated that in the whole population between $1\frac{1}{2}$ and 3 per cent. fell below the 70 line, that is, below the line which is commonly supposed to mark the boundary between mental defect and normality. The average of the boys was the same as that of the girls, but their dispersion was greater, that is, there were amongst them more who were very bright and more who were dull. This distribution has important implications, of which I shall consider only one, and that very briefly—namely, its bearing on the rate at which boys and girls leave school after completing the work of the primary school.

In Scotland about 44 per cent. of the children of age twelve embark on a secondary school course ; of these 70 per cent. begin the second year work, 43 per cent. the third, 22 per cent. the fourth, 15 per cent. the fifth, and 9 per cent. the sixth. Of those who pass to the 'Advanced Divisions' only 14 per cent. enter on a third-year course. These educational casualties are due to many causes ; some fall out for economic reasons, others find—or think they find—a better preparation for the serious business of life elsewhere (and these include some of the brightest), but probably most drop out because school seems to be a testing-ground rather than a training-ground, a means of picking out the brightest. This suggestion finds some support in the fact that it is the duller pupils who drop out first, the very pupils who are most in need of training. It has been estimated that a boy or girl must have an intelligence-ratio of 115 or over to profit without undue strain from a secondary school education ; this may be an over-estimate, but there can be little doubt that the average secondary school curriculum is unsuitable for the boys and girls whose ratios fall below the mean, that is, for half the school population. The bulk of the population are of average or nearly average intelligence—about 68 per cent. have mental ratios between 84 and 116—and it seems reasonable to ask whether a national system of post-primary education should not give first consideration to these rather than to the 16 per cent. at the upper end

of the scale who have the intellect and temperament that fit them for professional and administrative work.

There is no ground for suggesting that the enormous casualty list of the post-primary schools is due to poor teaching : indeed, there is distinct evidence that teachers are often attempting the impossible and coming very near to achieving it. The fault seems to lie rather in the nature of the curriculum, which, though suitable for the upper 20 per cent., is obviously quite unsuitable for the middle 60 per cent. It would be interesting to know what proportion of the men who sit on Education Committees, men who have earned the confidence and respect of their fellow-citizens, can pass, or have ever been able to pass, the ordinary School Leaving Certificate examination.

It may be suggested that the mental development of the duller elements of the population ceases at the age of twelve or thirteen and that, therefore, they have learned all they can learn by that age, whereas the mental development of their more brilliant fellows continues for several years longer. This suggestion is probably incorrect. We know that intellect develops more slowly in the dull, so that they fall farther and farther behind, but there is some ground for thinking that it reaches its maturity at about the same age. Further, the suggestion that the dull child has learned all he can learn by the age of twelve or thirteen implies a certain confusion of thought. Whatever may be the age at which maturity of intellect is reached, and whatever may be the level of development reached, it is certain that learning does not cease at that age : it can continue until senile decay sets in. The age at which maturity is reached has little or nothing to do with the age at which training must cease.

The open school door is a well-established tradition in Scotland : here the gifted child has ample opportunities of developing his talents ; but the practice of pushing all children along the same scholastic course studded with hurdles which must be jumped, under penalty of being left behind, is one which could be improved upon. As the intelligence-ratio seems largely to determine scholastic success, and as it remains approximately constant, at any rate during school life, and can be determined early, it should be possible to organise education on a basis of natural capacity. The early ascertainment of capacity and the provision of courses suitable for different grades of intellect would do something towards solving the problem of the backward child, who is often backward because he has not those aptitudes which are needed for success under the existing scholastic regime : he struggles to keep up, but ultimately, finding this too much for him, he gives up the race, sits by the wayside, and does not use even those gifts which he has. It would also make for health and peace of mind, for we have sooner or later to learn our limitations, and much mischief can be done by assuming that a boy has aptitudes which he does not possess. Experience in psychological clinics has brought this out all too clearly, for it has shown that many perversities of conduct are due solely to social misfits : the dull child of able parents who cannot live up to the expectations of his family may run wild, and one who cannot find a place in society to suit his talents and training is a potential source of mischief. A good deal of distress could be avoided by discovering a

boy's capacities, general and specific, during his school career, and especially when he is about to undertake the serious business of choosing a profession.

Mental tests offer an objective method of approach to the investigation of similarities and differences between races and between one generation and another, and perhaps also to the very difficult problems of mental inheritance. Racial differences have been investigated in countries like America and South Africa, where racial problems occupy men's minds. In Great Britain, where these problems are not so acute, little attention has been given to the subject : there have been some comparisons of Jews and Gentiles, of urban and rural populations, and of bilingual and unilingual communities. In America the testing of a whole army has been followed by numerous studies of the mentality of the races, white, black, yellow and brown, that constitute the American population. The general finding is that the Nordic races are superior to the Mediterranean in test performances, and the white to the coloured ; but it should be remembered that it is very doubtful whether the mentality of the European races can be estimated at all correctly from the samples, some of them very small, of their representatives in the U.S.A. Racial psychology will begin to stand on a firm basis when the scope of these inquiries has been extended and observations have been made on thoroughly representative samples. It is a pity that the lead given by Rivers, McDougall and Myers in their investigation into the sensitivity of the Murray Islanders and their susceptibility to illusions has not been followed more energetically.

These objective methods of investigating mental traits will also provide reliable information regarding the problem of the differential birth-rate. It has been shown repeatedly that the least efficient members of the community have on the whole the biggest families, and this has caused some concern, for it suggests a dilution of our intellectual stock-in-trade. What is needed is exact information about the intellect of parents, the number of births per family, the number of children who survive to establish families of their own, and their mental status, but there is very little of this. What little there is points to the need for further investigation, for it suggests that the casualties are higher among dull children, but that the losses are more than made good by the greater number of births, and that the problem is not so serious as some have maintained, but sufficiently serious to make this and other problems of mental inheritance worthy of investigation.

The study of mental inheritance has suffered sadly from a readiness to take over the crude concepts of everyday life : it has been concerned mainly with marked abnormalities—mental defect and insanity—and this, too, has hampered the study of the subject, for there is widespread opinion that these deficiencies and ailments are morally reprehensible—an opinion which is rarely expressed openly, but is enshrined in everyday speech and conduct. We have outgrown the practice of jeering at physical ailments and deficiencies, we care for the maimed, the sick, the deaf and the blind ; but dullness of intellect and mental disease are looked at askance, though the dullard has no more reason to be ashamed of his dullness than the genius has to be vain about his brilliance, both being apparently

matters of inheritance: moral judgments should concern only the use that is made of one's talents.

One serious difficulty in the study of mental inheritance has been that of defining and measuring accurately the characters under investigation: for example, mental defect can be, and is, defined in several ways, legally, clinically, psychologically, etc. In the legal sense it is a social concept, for according to the law the feeble-minded are 'persons in whose case there exists from birth or from an early age mental defectiveness so pronounced that they require care, supervision, and control for their own protection or for the protection of others; or, in the case of children, that they, by reason of such defectiveness, appear to be permanently incapable of receiving proper benefit from the instruction in ordinary schools.' However satisfactory this may be as a legal definition, it is useless both biologically and psychologically, for in the absence of any definition of mental defectiveness or arrested mental development, it means just inability to look after oneself and one's affairs without proper supervision. Obviously, inability to look after one's affairs depends very largely on the nature of those affairs, and so on one's social and physical environment, and since life is easier in some circumstances than in others, a man may be feeble-minded in one environment and not in another. If social environment becomes more complex and makes higher and higher demands on natural capacity, then, unless that capacity improves, the proportion of feeble-minded must increase. Some think that feeble-mindedness *is* increasing, and that this is due to differential birth-rate, but it is equally possible that the cause lies in the increasing complexity of civilised life: intellects that could live happily in a simpler environment may be finding the complexities of modern civilisation too much for them: there can be little doubt that to-day bigger demands are being made on children in the 'ordinary schools' than were made on them fifty years ago.

The influence on this social attitude is reflected also in the way in which mental defect, mental disease, criminality, pauperism, infantile mortality, and all kinds of organic disease are thrown together in serious investigations which purport to be investigations into mental defect, but actually are nothing more than inquiries into social inefficiency. It is possible that various traits that make for social inefficiency are associated in the same stock and may be the result of some common inherent weakness, but in the interests of clear thinking they should be kept apart until their causal relationships have been determined: a mind diseased may yet be capable of brilliant thought, and not all criminals are mentally defective.

The clinical varieties of mental deficiency which medical men meet, mongolism, cretinism, microcephaly, hydrocephaly, etc., are distinguished by anatomical rather than by either social or psychological characters. Psychologically, mental deficiency is usually defined in relation to performance at intelligence tests: the legally mental defective usually has an intelligence-ratio below seventy, so this figure is often taken as marking the line that separates the mental defective from the normal. This is an arbitrary method of defining mental deficiency; it has the merit of precision, but it is a precision which may be misleading when we begin to

investigate its genetic basis, for it is possible that feeble-mindedness may be due to one or more of a large number of genetic factors ; there may be different forms of feeble-mindedness which are not distinguishable by means of intelligence-ratios.

In investigations into the inheritance of intellect much reliance has been placed on rough-and-ready estimates based largely on social and professional success. In so far as such estimates are sound, these inquiries show that there is a correlation between the intelligence of parent and that of child, that bright parents have a higher proportion of bright children and that defective parents have a bigger proportion of defective children than do normal parents, but they have also shown that normal, even brilliant parents sometimes have defective children, that defective parents sometimes have normal children, and they suggest that the mental deficiency of children of either bright or dull parents may be due either to external causes or to defective inheritance. The main facts have probably been made out, but the details are lacking, and will not be available until exact measurements have been made of the mental traits of parents and their children under conditions in which social opportunities and encouragements are equal for all.

The theories of genetic inheritance which have proved so fruitful in the investigation of the physical characters of plants and the lower animals have been shown to apply also to human anatomical and physiological characters, such as the colour of the skin, stature, and susceptibility to disease, and it is probable that they apply also to mental characters ; if they do, then it is important that the characters should be distinguished and the manner of their inheritance traced out. The difficulties are great and for the most part obvious ; one is the difficulty of controlling environmental factors (the most humane method of overcoming this difficulty is to improve the conditions of life so as to give all a chance) ; another difficulty is that of finding really satisfactory tests for adults ; but perhaps the greatest of all is that of isolating and defining simple mental characters. Fortunately the last of these is a difficulty which we can hope soon to overcome, for the search for unitary mental traits has been proceeding vigorously, and there is now some prospect of diagnosing and measuring them, and so putting the study of genetic basis of mental traits on a sound footing. This will demand the co-operation on a big scale, not only of psychologists, but also of biologists, statisticians, teachers, medical men, and others, in which respect the study of mental inheritance resembles that of most other social problems.

SECTION K.—BOTANY.

SOME ASPECTS OF FOREST BIOLOGY

ADDRESS BY

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The forest with its associated flora and fauna is a highly complex and delicately balanced community. In it we find an abundance of material upon which much of our prosperity depends. Perhaps the best proof of this statement is that the consumption of forest products and the destruction of forests is increasing at a rate which, in well-informed quarters, gives rise to serious apprehension as to the ability of the forests to withstand increasing and continued unscientific exploitation.

The first users of the forest cared little for its timber. It was used principally for shelter and the chase. Later on, as population and settlement increased, wood was required for housing and fuel. In those early times whatever wood was handy and whatever trees seemed suitable to supply any requirement were utilised without any thought as to reproduction and maintenance of supplies. Thus began the system of forestry which at the present day, under more organised methods, is known as the selection forest. In the selection forest only trees of a certain diameter may be removed, the number and volume of the trees to be felled annually or periodically being regulated by measurements of rate of growth in the forest. The regeneration is a natural one. Seedlings in due course take possession of the spots from which the mature trees have been removed. We have thus all ages and kinds of trees in irregular mixture singly, or in very small groups, scattered throughout the forest. This system preserves, more closely than any other, the conditions which prevail in and characterise the primeval forest. It has many advantages, but the main disadvantage is that the volume, and perhaps the quality of the timber as a whole, is not so high as that which can be obtained under more artificial systems of forestry. It is here that the main problems in regard to success or failure arise. When man interferes too much with Nature, she inevitably replies by countering his efforts, unless they comply within certain limits to natural laws. The endeavour to grow pure forests of trees on wide areas, in dense, uniform, even-aged masses, irrespective of changes in soil conditions and climate, is not in accordance with natural laws. In converting the virgin forest or the selection forest into the modern artificial forest, the principal aim was to secure uniformity, and that branch of forestry known as forest management came into existence. The principal aim in forest management was to obtain the highest yield in the shortest time. For the sake of ease in regularity of yield or utilisation,

the forest was subdivided into working units called compartments, and for the sake of uniformity in working, these compartments were made as large as possible, with little or no regard to local variations in soil, climate and exposure. To a large extent the laws which govern tree growth and the possibilities of silviculture were ignored in favour of artificial formulæ. This trend in forest management naturally led to a preference for pure stands—that is, large timber stands of the same species. The variation in species and age differences which characterise the primeval forest disappeared on its conversion into artificial forest, and much of the naturally associated flora and fauna was destroyed. It was easy enough to get so far, but difficulties arose when the questions of sustained permanent yield, conservation of soil fertility, and the reproduction of this kind of artificial forest came to be faced. It is here that the inseparable connection between botany and forestry becomes all-important, and I hope to be able to show, by a brief reference to certain factors which govern tree growth, how important is the study of botany, especially plant physiology, ecology, anatomy, and plant geography, to the forester. In the northern hemisphere, from the subtropics to the Arctic and alpine limits of forest growth, certain well-defined climatic forest zones can be recognised. I here adopt Prof. Mayr's subdivisions: the tropical forest zone, the Palmetum ; the subtropical zone of the evergreen oaks and the laurels, the Lauretum ; the temperate warm zone of the deciduous broad-leaved forest, warmer half, the Castanetum ; the temperate warm zone of the deciduous broad-leaved forest, cooler half, the Fagetum ; the temperate cool region of the spruces, silver firs and larches, the Picetum, the Abietum or the Laricetum ; finally, the cold region of dwarf trees and scrub, the Alpinetum or the Polaretum. Each tree has a certain natural range of geographical distribution. By 'tree' is meant anything not less than 25 to 30 ft. in height. It has a cold limit, a warm limit, and between these an intermediate or optimum region of distribution. The factors which make up climate—e.g. such as temperature, aqueous precipitations, relative moisture of the atmosphere, and light intensity—vary from the optimum to the cold-and-warm-range limits of each species, and the trees react accordingly. The optimum region is where the general balance in climatic factors is the most favourable, but deficiency in any one growth factor may be made good or compensated for by the more favourable condition of other growth factors. It happens, however, that as a general rule, ultimate height growth, diameter increment, volume production, form of bole, crown balance and development, seed production, and ease and certainty in establishment and after care are less troublesome and less costly in the optimum than elsewhere. In the southern or warmer climate, rate of growth is, to begin with, quicker than in the optimum, but it falls off sooner and, about middle age, rate of growth falls behind that of the optimum. Hence to obtain the best results in the cultivation of any species we must study its growth and habit and form throughout its entire range of natural distribution. This brings us now to the question : Is there such a thing as acclimatisation, or do trees possess the property of adapting themselves to climatic conditions which are new or different from any climate within their natural

geographical limits ? This is a question of considerable scientific and economic importance, and concerns both the botanist and the forester. A complete survey of the form, habit, and growth of a tree within the limits of its natural range shows undoubtedly that each species can and does react to different environmental conditions, but opinion is by no means unanimous that these external conditions can bring about permanent change of an hereditary character. Late and early frosts are very troublesome and do much damage in the nursery, young regenerations and newly planted areas. Attempts have been made to obtain frost-resistant trees by collecting seed from the higher and colder elevations in the mountains, or from the northern and colder limits, but all such attempts have not yet solved the problem as far as frost-hardiness is concerned. A short consideration of the behaviour of young plants transferred from a colder to a warmer climate, and *vice versa*, may serve to bring out some points of interest in this connection. The four seasons vary in relative duration and climatic character according to latitude and elevation. This determines the length of the active period of vegetation. The critical seasons are spring and autumn. A certain amount of heat acting for a certain time is required to awaken the plant into vegetative activity, while the fall in temperature at the end of the vegetative season controls the rapidity and completeness of ripening and preparation for the resting season in winter. As regards the length of the active period of vegetation, the controlling factor seems to be the average temperature during that period. Further investigation concerning the commencement of vegetation and meteorological data are required, but as far as available information exists it would seem that each species of tree has an average temperature-constant which is necessary during its seasonal vegetative period. This period of average temperature is longer or shorter according as the tree is on its southern or northern limit. The effect of climate merely lengthens or shortens the period of vegetative activity, but the specific average constant of the tree is in no way altered. This has been called the vegetation therm by Prof. H. Mayr, who states that 14° C. is the constant for the larch, and probably also for the spruce. If such a figure could be fixed for all trees its value would be great, but this investigation necessitates further meteorological data and phenological observation. To return now to the question of the transference of a living tree from a warmer to a colder climate, or from a sheltered nursery to bare exposed planting ground. The chances are that if the transference takes place in autumn, the plant will suffer from early and winter frost. The plant has ripened off and prepared or attuned itself during the previous summer for the approaching winter conditions in general balance with the warmer climate, and it is not prepared for the earlier and more rigorous winter of the colder climate. On the other hand, if the transference takes place in spring after the winter resting period in its accustomed warmer climate, it has all the growing period in front of it, in which to adjust itself to the new conditions of the changed colder climate. This cannot be called acclimatisation, since the changes in the plant itself are not constitutional and hereditary. The tree will react to changed climatic conditions within its natural limits of distribution, but that is all. If a tree could be

got to grow normally up to full maturity, and to produce fertile seed, in a climate warmer or colder than that of any climate in which it is found within its natural range of distribution, then and then only it would seem that we could speak of acclimatisation. Trees have a certain amount of plasticity and can alter their form, rate of growth, and stature to a surprising extent in response to external growth factors, but such reaction changes are not permanent and hereditary. Trees vary in their demands for light: some are more tolerant of shade than others; nevertheless, all trees will show definite symptoms of want of light if grown in too dense shade. Small scanty leaves and needles, thin attenuated twigs, small buds, a gradual flattening and broadening of the crown, as well as certain internal anatomical changes, are some of the symptoms. In a dense forest, trees may pass their lives in varying degrees of overshading and yet we find that individuals, or their seedlings if any, are always ready to respond by normal growth to increased light intensity. There is no trace here of reaction changes to light becoming permanent and hereditary. Again trees, some at least, can grow in a fairly wide range of soils, but in no case, however gradual the transition, can we induce the deep-sinking tap-rooted oak to grow normally in shallow soil. Nor by the reverse process can we get the shallow-rooting spruce to form a deeper root system by cultivating it on deep soils. In these and other cases, the results would be very valuable, but all the tree does is to temporarily react in growth and habit according to variations in the soil.

In forestry the long period which must elapse between the establishment of a crop and its final harvesting at maturity makes it imperative that we should use every endeavour to secure the best types of trees suitable for the concrete conditions of the localities in which they are to be grown. If a wrong species is chosen at the start—that is, a species unsuited to the soil or climate—and in mixed woods, if a wrong combination of species is adopted in their formation, then no amount of skill, care, and attention on the part of the forester can remedy the defect or make full use of the productivity or growth factors of the locality. In cultivating his crops the forester must always keep in mind that the ultimate success of his efforts is determined by rate of growth combined with the usefulness and volume of the timber produced. This again brings him into close contact with the botanist. Among species of trees, apart from varieties and sports or mutations, no two individuals are absolutely identical, in spite of all outward resemblance. There are differences in rate of growth; commencement and duration and finish up of seasonal vegetation; flower, fruit and seed production. All these may vary in time from a few days up to as much as one or two weeks. These differences may occur in all soils and in all climates. In both the artificial and the primeval forest it can be detected among trees of the same species, growing side by side on the same soil and sprung from seed of the same parent tree. Individuals from the same seed may show differences in stem quality, branch formation and crown balance, due to some internal impulse, which is independent of soil or climate. Some individuals produce straight cylindrical stems, others bent, twisted and crooked stems; some have an inherent tendency to fork and produce double

leaders—accident to the end bud of a leading shoot may cause double leaders, but that is a different thing ; in some the branches ascend at an acute angle, in others they tend to spread horizontally at right angles. Forking leaders and spreading branches result in defective crown formation. Another individual defect is the tendency to produce water shoots or epicormic twigs. Unfortunately this individuality does not seem to be hereditary, otherwise we could with greater certainty avoid such in selecting our growing stocks, but even if this were possible we would still have to face the fact that defect in stem, branch and crown and rate of growth is not due to individuality alone. Although the characteristic individuality remains constant throughout the life of each single tree, it does not follow that its seedlings will all possess the same characteristics : each seedling will have inherited an individuality, but not necessarily the same as that of the parent tree. Nevertheless, rate of growth and tendency to late or early vegetation become apparent early in the life of the seedling. It is then that the first choice can be made in the selection of growing stock. But no matter how perfect the young tree may be, it is still subject to the influence of external growth factors, and climate, soil and silvicultural treatment can influence its form and growth. A plant with individual tendency to slow growth in the colder limits of its distribution will be stimulated to more rapid growth in the warmer climate ; and, on the other hand, a rapid-growing individual of the warmer climate, if transferred to the colder climate, will suffer check to its rate of growth, and individuals of normal growth will show the same tendency. Keeping these facts in mind, it is easy to see how readily false conclusions may be drawn in regard to the actual and relative rate of growth of different species. In a community of trees of different species growing on the same soil and in the same climate, some may be in their optimum, while others may be on the colder or warmer limits of their natural habitats, and the soil may suit some species better than others. If such an experimental plot were established by planting, allowance would have to be made for the time taken by different species to get over the check stage and to become completely established in their new quarters. Some species are quicker to re-establish themselves than others. That is, they are more easy to transplant. Then again, trees are not uniform in their rate of growth at all ages. We must, therefore, be careful in coming to conclusions regarding the growth behaviour of trees. We must seek the aid of plant physiology and plant geography if we wish to arrive at reliable and useful conclusions. Climate is after all the main controlling factor, and each country must collect its own data. Hitherto, in forestry, we have had to rely too much on data applicable to the continent of Europe. But with a well-selected series of representative sample plots established throughout Britain by the Forestry Commission, the arrears of our knowledge in this respect are being made good rapidly.

Let us now consider the importance of these fundamental biological facts to silviculture. For convenience let us divide the life of the forest into three stages : the juvenile stage, the pole or stage of most rapid height growth, and the adult or tree stage ; and, in order not to obscure the main points by unnecessary detail, let us assume that the trees have

been artificially planted. In all recent plantations there is bound to be competition by weed and grass growth ; it may be also woody scrub, stool shoots, or interloping and unwanted light-seeded invaders. Cleaning and weeding must not be delayed. Careful tending of the young trees should begin early. Too often plantations are left to look after themselves until they are supposed to have arrived at the thinning stage, when they may yield something in the way of returns for the cost of thinning. But by this time irreparable damage may have been already done to the growing crops. Not only is weeding and cleaning necessary during this period, but now is the time to remove and replace trees of inferior growth habit, which they begin to show at this early stage. Trees which naturally tend to fork cannot be improved by pruning off one of the leaders : forking will be repeated later on, as this natural individual tendency persists throughout the life of the tree. The same thing applies to all trees with faulty stem and crown formation. Among all species, but more especially among broad-leaved trees and in particular the beech, it is these heavy-branched, spreading-crowned, short-stemmed trees which may forge ahead and become predominant in the mature stand at the cost, it may be, of smaller but better-formed and more valuable trees. Therefore by the timely removal of such individuals, so-called wolf trees, much future trouble, cost and loss will be avoided. A certain amount of thinning may be advisable before the pole stage is reached, but such operations should be confined to completely suppressed, back-going and dead trees and aggressive, malformed wolf trees. For various species under average conditions the period of the pole stage falls between the twentieth and the fortieth year. This should be the time of greatest density in the life of the stand. The trees have reached the stage of their most rapid annual growth in height, and this is further stimulated by the density of the stand, which also leads to lateral branch suppression and the cleaning of the stems. The density must not be too great, otherwise the trees are liable to become too long and attenuated to carry their own weight. It is here the skill of the forester is put to the test. Now is the time, and indeed the best opportunity, during the whole life of the stand to encourage length, form and cleanness of stem. Growth in height is dependent upon crown room and light ; and cleanness of stem is dependent upon crown density and shade. These two opposing conditions must be so balanced that the one will not defeat the object of the other. The thinnings during this period will depend upon the planting distance originally adopted and the amount of care and attention which has been given to the young growth until the branches meet and establish cover or canopy when the thickest stage is reached. The maintenance of pole stage density is prolonged until the side branches have been killed off, by side shade, up to the desired height on the stem. Subsequent drying, decay and fall is merely a matter of time. Up to this stage, which will occupy as a general rule the first half of the rotation, the main endeavour is to secure a good growing stock of tall, straight, clean-stemmed trees. In the second half of the rotation, which we have called the tree stage or adult stage, the problem in tending should resolve itself into obtaining the greatest volume production and quality of timber by encouragement and control

of diameter increment. The quality of timber depends to a large extent upon uniformity in breadth of the year rings and the texture and fibre of the wood. This can only be obtained if the growth of the tree itself is uniform and sustained. Hence in this latter half of the rotation attention must be directed to the crowns and roots of the trees. A gradual removal of certain trees and opening up of the canopy gives the crowns of the remaining trees more light and room to expand, and this means increased food production. These cuttings may be called 'light increment cuttings,' in contradistinction to 'thinnings,' from which they differ in regard to their influence on the biology of the stand. The more open growth under light increment treatment means fewer trees at maturity, say 160 per acre, but individually they are of greater volume and collectively of not less volume than would have been produced by a larger number of trees in closely crowded crown competition. The more open stand necessitates the retention of some kind of undergrowth or, more commonly, underplanting for soil cover and preservation. This method has been successfully practised in Denmark in the case of beech, oak, pine and spruce. Under the old system of dense canopy preservation, the intermediate yield in thinnings was about 25 per cent. of the final yield. Under the light increment treatment the thinnings may amount to 20 per cent. and the light increment cuttings to 50 per cent. of the final yield. That means in the latter case we have 75 per cent. against 25 per cent. in the former; and if we assume, as we are entitled to, that the value of the material removed in light increment cuttings is greater per unit of measurement than that of thinnings, and at the same time if we keep in mind the fact that the volume of the final yield is the same in both cases, with the balance in favour of quality in the case of light increment treatment, it will be seen that the treatment increases the yield per acre by well over 50 per cent. The material removed by the light increment cuttings, from the fiftieth year onwards, would be clean grown and straight, and would yield all sizes required for telegraph poles, for which the demand has always been high. The trees of the final crop would easily be of sleeper size—that is the most all-round useful and valuable size for mature timber. If this can be done in Denmark, why should it not be possible in our equally favourable if not more favourable climatic and soil conditions?

All the problems which arise in regard to the care and treatment of young, middle-aged and maturing stands of trees, are subjects of the study of stand biology, and that system of silviculture which makes the fullest use of the external factors of growth, in combination and individually, will achieve the best results in the end. The old system of preserving dense, uniform, unbroken canopy was unnatural and made it impossible to utilise to its full advantage the important growth factor, light.

In the primeval forest, loss and replacement is constantly going on. As each veteran disappears it is replaced by hundreds of seedlings which strive and struggle among themselves and against surrounding hindrances to reach the light. The struggle is a prolonged one, and many seedlings and saplings are killed off in the process. Still, Nature works cheaply if slowly, and if we can make use of the free gift she offers in the way of natural regeneration, it would be an obvious gain. Nature has produced

and maintains the forest for her own purposes. On the other hand, man exploits the forest for his comfort and wellbeing, but if he oversteps certain limits in his treatment of the forest for the sake of extra gain or profit to himself, Nature revolts, with the result that man defeats his own ends.

If we are to make use of Nature's free gifts, in the natural regeneration of the forest, we must study the natural biological laws under which the process can take place. As we have seen, Nature works slowly but surely in her conservation of the primeval forest, irrespective of what the utility and value of the species may be to man. Man's idea is to grow certain species only in massed, even-aged assemblages, in order to obtain the maximum amount of timber of the kind, size and quality he wants, and if he expects Nature to help in the quick and certain regeneration of these artificial woods, at the end of what he considers the most advantageous age or rotation, he must make certain provisions in accordance with natural laws. This can be done by appropriate silvicultural treatment. The trees must be of a suitable seed-producing age, the forest floor must be in a suitable condition for the reception and germination of the seed, and the conditions of light, moisture and temperature must be suitable for the future growth and development of the seedlings. These three things are of fundamental importance. In most of the mature and maturing woods which have been treated under the strict artificial rules of so-called forest management, the question of quick and certain natural regeneration often presents insurmountable difficulties. At the time required by the working plan the trees may not be in a suitable condition for flowering and seeding ; the forest floor, under light demanders, may be long past the best conditions for the reception and germination of seed, owing to weed growth, and under shade bearers an over-abundance of humus, especially raw humus, is equally unfavourable. Many years are required to bring the trees and the forest floor into a suitable condition for natural regeneration, and if this is attempted over a whole compartment simultaneously, the result is seldom satisfactory. In dense-canopied, even-aged stands a series of preliminary fellings, called preparatory fellings, must be gradually carried out to allow more light and room for the selected seed trees, in as even distribution throughout the stand as possible, and also gradually to prepare those trees for their more isolated conditions and resistance to wind. Under shade bearers this opening up of the canopy leads to the disintegration of over-abundant humus by allowing more direct access of precipitations and light, and also by increased aeration due to the freer circulation of the air. Under light demanders it means costly artificial surface and soil preparation. In either case, when the soil is in its most suitable condition a further felling is made either immediately before or during a seed year, if one should happen to occur at the right time ; if not, it means delay and the soil gets past its best condition for seed germination. Even if a seed year should occur at the right time, there are many climatic and weather conditions which may prevent complete and uniform regeneration over the whole area : only patches of seedlings may occur here and there. This means waiting for a second seed year, which may be five or ten years hence, meantime

further deterioration in soil conditions and risk of storm damage to the seed trees which were isolated so late in life. The only alternative in such cases is to complete the process by clear cutting and artificial planting, and this is what generally occurs. If, as sometimes happens, by good luck the regeneration is sufficiently complete to provide a new crop, then the old trees are gradually removed in a series of falls, called the final fellings. But the whole process known as the uniform or compartmental system is slow, uncertain and risky. To lessen the risks of failure and loss by opening up large areas at one time, numerous modifications have been introduced into the practice of forestry. The underlying idea was to confine natural regeneration to smaller areas, in the shape of groups or strips, with peripheral extensions of these as they became regenerated. By selecting the shape, breadth, line and direction and sequence in time of the strips, a considerable amount of success has been achieved. Strips or groups may be clear felled or a certain number of trees may be left to provide seed and to protect the young seedlings. In the former case, protection is supplied by the adjacent stand of mature trees, and seeding takes place from the side. Various and numerous combinations of the uniform, group and strip methods have been tried, with more or less success, under certain favourable locality conditions.

The main trouble is that in the past the woods have not been managed with a view to natural regeneration; under light increment treatment, the more open canopy and crown room enables the trees to respond almost immediately to the influence of the seed felling. The under planting which has kept the soil in a favourable condition for seed reception can be dealt with easily, and after the seedlings have appeared, the old trees may be removed at one felling instead of gradual removal over a protracted series of years, as a certain amount of undergrowth can be left to provide shelter and protection to the young trees.

The biology of the large pure stands of timber must obviously differ from that of large mixed stands, consisting of two or more species, as generally prevail in the primeval forest. To establish artificially or to regenerate naturally a mixed stand of timber which will have the desired ratio of species at maturity, involves much labour and cost, and the attempt is not always certain of success, except perhaps under the selection method of treatment. To get over the difficulties associated with single stem mixture, other forms have been tried, such as planting the different species in alternate rows, bands, strips, clumps and groups, but still this does not quite solve the problem. It is all right for the trees in the centre of the group or strip, but those on either side at the contact margins are apt to become bent and branchy; further, each of these numerous units requires individual attention, and this is not compatible with economic management. It is possible with certain light-demanding and shade-bearing trees to form mixtures in which the crowns of the light demanders form a kind of upper storey, with those of the shade bearers beneath; but such mixtures are very difficult to bring through the pole stage of growth unless the light demander happens to find itself in its optimum conditions.

The problem may now be stated: How are we to manage and develop our woods so that the demands for different species of timber, sorts and

sizes of the highest quality possible, may be met, and adequate provision made for the regeneration of these woods, without loss of time and without deterioration to the productive capacity of the soil, and at the same time make as full use as possible of all growth factors, without interfering too much with the natural laws of forest growth ? This is a big and important question, and in my humble opinion the solution suggested by Prof. Heinrich Mayr of Munich seems to fulfil all these requirements. His suggestion was to compromise between the economic objects of man, the user, and the natural laws which govern the designs of Nature, the producer. He suggested that the forest should be made up of small compartments, 1 to 8 acres, each compartment to consist of one species. These small pure compartments would be scattered as much as possible, so that adjacent compartments would differ in age and species. We would thus have a forest of mixed small compartments differing in age and species. Due attention would be given to assigning each species to its most suitable soil and exposure. Where conditions were such that only one species would grow satisfactorily, owing to physiographical conditions, such as in the mountains, pure sand, wet soils, cold climate, the compartments may be larger, about 14 acres, if desired, and the same species may adjoin each other, but the age difference between adjoining compartments should be varied. The present division of the forest into large compartments need not be done away with, but each large compartment should be subdivided into sub-compartments—small compartments—which would become permanent units of management. Each small compartment treated from its earliest stages with a view to natural regeneration would, under later light increment treatment, always be in such a condition that natural regeneration could be imitated without long and costly preparation. The process could be completed within five years, and the risks of failure would be small compared with those of large contiguous areas, where ecological and biological conditions vary. In the small stand, the more open stand of the trees under the light increment treatment and the shelter afforded by adjacent stands would eliminate the necessity of the risky and lengthy preparatory fellings—a seeding felling and one final felling would suffice. Thus, as Prof. Mayr claims, natural regeneration could be made easier, speedier, and safer. The danger and risks from wind, fire, insect and fungus epidemics would be lessened ; the varied demands for different kinds, sorts and sizes of timber could be more easily met. The forest community as a whole would approximate that of the primeval or natural forest, and the productivity of the soil would at least be preserved, if not improved.

To turn now to another aspect of the forest as a living community of plants and animals. The forest is perennial, and less subject to seasonal changes than other forms of massed vegetation. The tree stems raise their crowns of branches, twigs and leafy canopy high above the forest floor, and this has a marked influence on the light, temperature and moisture conditions within the forest. Light is subdued, but temperature and moisture are both increased, and this, combined with a relatively still atmosphere, render the conditions within and under the crowns of the trees quite different from those of open country. Under the leafy canopy

the soil surface vegetation consists mainly of shade-loving shrubs, herbs, ferns and mosses. The leaf fall from the trees and the general organic remains, along with that of the undergrowth, produce a soil covering of disintegrating organic matter, generally referred to as the humus layer. This layer acts like a mulch and ameliorates and conserves soil moisture and temperature. The tree roots penetrate more deeply into the substratum than most forms of other vegetation, this increasing its aeration, permeability, and water-holding capacity. Although it has not been definitely decided whether forests increase the rainfall or not, it can be claimed with every justification that the forest is of great importance as a conservator of water and as an equaliser in the drainage of the land. Where no forests exist in the upland or collecting regions of watersheds, the rain falls unhindered, beating the surface hard or eroding it down to the bare rock. There is nothing to check the downward rush of water, which collects into mountain torrents which gush unbridled into the main rivers and streams, causing them to become swollen and flooded. These in turn race through the fertile valleys to their outlets, tearing down and overflowing their banks. The damage done by severe and sudden floods to roads, bridges, agricultural crops and stock, including human habitations, is well-nigh incalculable. Nor does the matter end there : millions of tons of valuable soil is washed away in these turbulent floods, and deposited as barriers in the river beds or in the sea at the river bar. Harbours and docks at the outlet of our main rivers become silted up with mud and debris : this in turn—apart from the loss of soil—involves costly dredging operations to keep the navigation channels clear.

Where forest exists in the upland districts or collecting ground of the water, rivers are more uniform in their flow, year in year out, and carry much less silt and debris. The crowns of the trees break the force of the falling rain ; the humus layer on the forest floor has an enormous water-absorbing capacity, and when saturated it allows the water to percolate slowly into the deeper loosened layers of mineral soil, from which in turn it gradually finds its way into springs and watercourses. Further, the influence of the forest is such that the melting of snow is more gradual and water is slowly absorbed and held, thus again avoiding floods. The forest regulates the off-flow of water after heavy rains or melting snow. This water is fed into springs and watercourses more gradually throughout the year, thus preventing floods at one season and equally serious drought at another. As regards the influence of the forest in lessening the destructive effects of cloudbursts, we have it on the authority of Fernow that : ' The Forest litter, the moss-covered leaf-strewn ground, is capable of absorbing water at the rate of 40,000,000 to 50,000,000 cubic feet per square mile in 10 minutes, water whose progress is delayed by some 12–15 hours after the first effects of a heavy freshet have passed.' I do not claim that afforestation or forest conservation in the high ground and valley slopes will entirely prevent floods and drought, but what the forester is doing or leaves undone in the remote hinterland will go a long way to check or ameliorate the evil effects of both. I have referred to these facts because the biological influence of the forest is so important and widespread in regard to drainage and water supplies.

As a form of vegetation which rises high above the surface of the ground, the value of the forest in breaking and tempering the effects of the cold winds has long been recognised and appreciated by the agriculturist. An adjacent sheltering strip or even clump of trees exercises a marked influence on farm crops and pasture lands ; stock also thrive better in the shelter afforded. The trees afford shelter and at the same time exercise a very marked influence on the rate of evaporation of moisture from the surrounding area ; this influence, in lessening the surface velocity of the wind and rendering it more moist, may be noted up to between 300 and 400 ft. from the trees, but the distance varies with the height of the trees. In spring the pasture is earlier and more abundant, while in the autumn it remains longer green. The question of a reasonable balance between forest and grazing land is one of considerable biological and economic importance.

In the time available it is obviously only possible to refer to a few aspects of forest biology. I would have liked to say more about the importance of plant geography, but probably enough has been said to indicate how important this branch of botany is to forestry. Plant physiology and ecology are also of the highest service in the applied science of forestry. Plant anatomy is likewise of great value in wood technology, timber identification, seasoning, testing and preservation, which are all very materially helped by a knowledge of wood anatomy. It is needless to say that without the help of the botanical systematist the forester would frequently find himself in serious difficulties, while the mycologist is equally indispensable.

Many biological problems of first-class importance in silviculture have still to be tackled, and it is to botany that the forester must look for their ultimate successful solution.

SECTION L.—EDUCATIONAL SCIENCE.

SCIENCE AT THE UNIVERSITIES:

SOME PROBLEMS OF THE PRESENT AND FUTURE

ADDRESS BY

H. T. TIZARD, C.B., F.R.S.,

PRESIDENT OF THE SECTION.

THIS section of the British Association for the Advancement of Science rejoices in the impressive title of 'Educational Science.' To judge from its past proceedings the range of its interests is so prodigious as to daunt one like myself, who neither pretends to be an educational expert nor belongs to the large body of enthusiastic amateurs who hold such pronounced and varied views on the education of other people's children. The only way in which I can hope to justify my selection this year as President of the Section, an honour that I deeply appreciate, is to devote most of my address to matters of which I have first-hand knowledge and experience. If I occasionally appear to be too didactic, please attribute this only to my desire not to be long-winded; while if, in speaking of Universities that I know best, I make remarks that are not applicable to Scottish Universities, please forgive the ignorance of a Sassenach.

We have lived, and are living, in times of absorbing interest. I was at a public school at a time when to take an interest in science was held to be a sign that you were not quite a gentleman. At my school there were 'close' scholarships to Oxford and Cambridge, but I was soon given to understand that these were not available for boys on the science side. They were made so available soon after I left, at about the time when baths were first installed in college—an interesting coincidence of sanity and sanitation. It does not seem so very long ago to me; yet the changes that have taken place since then are so profound that it is now considered quite respectable to be a scientist, even at a public school. I wonder if any generation will ever see such far-reaching changes as we have seen in so short a space of time! When I reflect that our better conditions of life, better health, greater opportunities for interesting and useful work and recreation, have been mainly brought about directly or indirectly as the result of scientific education and research, I wonder that some distinguished men have fallen into a gentle melancholy with advancing years, and tend to dwell in public and in private rather on the mistakes than on the achievements of this brilliant age. Mistakes there must be when progress is rapid. One difference between these and other times within living memory is that a few years of madness have revealed weak spots in the structure of civilisation that would otherwise have been discovered only

after many years of slower progress ; just as a motor race shows up in a few hours unsuspected defects in the mechanism of a car. The economic foundations of industry and trade have not suddenly become unstable and weak : they always were so, but we did not observe it. The gold standard has not suddenly become imperfect ; its imperfections have been made obvious. Human nature has not changed for the worse ; but we are all more conscious of the deficiencies of others than we are in placid times. I think we should do well to emulate the robust spirit of the practical engineer, who after a partial failure spends little time in wondering whether his work is really worth while, but uses his experience to make a better article.

The great practical achievements of science have naturally brought about a change of attitude on the part of the general public towards scientific education and research. Everyone believes in scientific research, without knowing quite what it means. Thirty years ago a member of Parliament advocating the need for scientific research would as likely as not have emptied the House : to-day I should be inclined to say of the House of Commons that it is not sufficiently critical of expenditure on research, because its faith is greater than its understanding. A scientific man need no longer spend tedious hours in advocating the value of a general scientific education, because he has many convinced and influential supporters who themselves never had any scientific education. The chief problem now is to define what we mean by 'a general scientific education,' and on that there is little agreement. Should it include biology, and if so, of what kind, and to what extent ? How much laboratory work should be done ? How is it possible, in a few years, to give a boy some insight into the beauties and wonders of the physical and biological sciences, some real conception of law and order in the universe, some true appreciation of scientific method, without running the risk of leaving him with a mere smattering of uninspiring knowledge ? I do not propose to offer any advice on these important matters to schoolmasters, because I honestly believe it would be of little value to them. Further, I do not think the questions can be finally answered by discussion, but by experiment ; and I am content with the thought that the experiment is being tried in different ways in a number of schools, by enthusiastic science masters, who meet every year to exchange views and experiences and to keep their own knowledge up to date. After all we must remember that the teaching of science at schools has not centuries of experience behind it, and we must expect imperfections. Classical education has a much longer history. The value of the Classics lies not so much in the intrinsic merits of Latin and Greek, nor in the importance of the opinions and work of people who lived in a primitive state of society thousands of years ago, and who, in the words of an old friend of mine, 'had access to so little information,' as in the way it is taught ; and the way it is taught is the result of hundreds of years of ruthless experiment on unhappy boys ! Science masters, who are intensely self-critical, so much so that they invite, and get, the criticism of others, must often envy the calm confidence of their classical colleagues, who teach admirably a subject that is, to all intents and purposes, a closed book, while they, on the other hand,

have constantly to be adapting their instruction to the advance of knowledge. They can take heart from the thought that theirs is a living subject, which will assuredly become the basis of all good education as time goes on. I cannot imagine the Classics being widely taught in 500 years' time, and I cannot imagine a time when science will not be taught. A young child is naturally scientifically minded: he makes experiments; he wants to know 'why'; it is only as he grows older that he gradually loses his eager curiosity, because his parents, in their ignorance, are unable to satisfy him. But the inability of parents to provide reasonable answers to the simplest questions of children is gradually disappearing as the result of better education and the provision of better and more accessible scientific and technical literature; every year the chance becomes greater that the inquiring minds of children will be stimulated and not stifled. No scientific man desires to see scientific education pushed to the neglect of literary studies; all of us recognise that a properly balanced diet for the mind is as important as for the body: what we do think is that science, well taught, can supply all that is best in the classical tradition; can 'teach accuracy and exactness; can give a discipline in clear thinking; can teach boys to recognise differences in things which seem alike; can brace with its difficulties minds that are not afraid of difficulties; can inspire with its beauty minds not insensitive to beauty'—to quote the recent words of the Headmaster of Rugby in praise of Greek.

The general growth in the teaching of science at secondary schools has naturally been accompanied by a great increase in the number of students of science at universities. There are now about 50,000 students in the universities of Great Britain, half of whom are studying some form of natural science. This growth has been only made possible by the provision of public money; all universities in this country are now dependent on the taxpayer and ratepayer. The State alone provides annually for university education a sum nearly ten times as great as was provided before the war; and local government bodies, in addition to their direct contributions, find large sums for maintenance allowances to students. The student of science has to be provided with laboratories, where he consumes power, heat, light, and expensive material. He is in consequence the most costly of university students: I estimate that the public expend, in one way or another, nearly £200 a year on each student of science, with the possible exception of students at Oxford and Cambridge, who are more richly endowed from private sources.

This public expenditure has laid additional responsibilities on the teaching and administrative staffs of universities. Most of us are now in the position of Public Trustees; we have to examine our expenditure more scrupulously than we should if we were not (indirectly) responsible to the public, and we have continually to ask ourselves whether additional expenditure can be justified. There was a time when it was feared that the autonomy of universities would disappear if the State provided a large measure of financial support; that this fear no longer exists is due to the work of the University Grants Committee. I shall have reason to base some of my subsequent remarks on extracts from the reports of the

University Grants Committee ; at this point, however, I should like to say a few words about its general influence.

There will be general agreement that the establishment of the University Grants Committee was an event of first-class importance. So far as I know, it has no counterpart in any country. By a stroke of administrative genius, most of the fears with which universities naturally regard any suspicion of interference by Government departments were dissipated. Everything that has happened since has strengthened the relations between the Committee and the universities. We read the reports of the Committee with profit, look forward to the visits of its members with pleasure, and welcome their criticisms and advice. We find ourselves masters in our own houses ; untrammelled by political influence ; trusted guardians of public money. We are so used to this happy state of affairs that it needs a convulsion in a foreign country to make us realise our good fortune. Universities owe a great debt to all the distinguished members of the Committee, and especially to the two Chairmen and to the late Secretary, Mr. A. H. Kidd. The sudden death this year of Sir Walter Buchanan Riddell came as a great shock to many of us. That deeply loved and trusted man, Sir William McCormick, set a standard difficult for others to live up to ; but when Sir Walter Buchanan Riddell, who was the first Secretary to the Committee, was appointed to succeed him, everyone felt that the happiest choice had been made. The few years that have passed since his appointment have been all too short for the full exercise of his constructive influence, though long enough for universities to realise that in him they had a worthy successor to Sir William McCormick. Mr. A. H. Kidd, who died a year ago, was an old friend and contemporary of mine at Oxford. He was a man of rare distinction of mind and charm of character, who was prevented only by continuous ill-health from reaching one of the highest positions in the Civil Service. He used his great powers, quietly and unostentatiously, to promote university education. I feel sure that I shall be forgiven for digressing a little from my subject in order to express, very briefly, our gratitude for the work of these men.

I have already referred to the high cost of teaching science at universities. I find it useful to look at problems of education from a financial point of view : it clears my mind, without, I hope, clearing it altogether or destroying my ideals. Take the position of the public schools as an example. There is much criticism of the public schools. We hear that they do not win a fair proportion of scholarships at the universities in comparison with grant-aided secondary schools ; that their hold over the higher division of the Civil Service is disappearing ; that altogether they are behind the times. Consider, however, their financial position. Most of them get no grant from public funds : they have to rely on endowment income (often small) and on the fees paid by parents. Many of them doubtless have their financial anxieties ; but at least they are solvent. It is indeed remarkable that through these years of serious industrial depression the public schools have remained full to overflowing ; tens of thousands of parents have thought it worth while to sacrifice a large part of their income, or to diminish their capital, in order to give their boys the benefit of a public school education. It may be said that their action is

partly dictated by snobbery, and partly by the feeling that the market value of a man is increased if he is known to have been educated at a public school. Snobbery doubtless has some influence, but surely very little ; and if the market value of a public school boy is on the average higher than that of boys educated at grant-aided secondary schools, it is not merely because of the reputation of his school, but because he learnt something there that he could not get elsewhere. The obvious answer of the public schools to all general criticism is that it is not compulsory for anyone to send their boys to them. So long as they perform a useful function they will continue to exist and to be solvent ; when they cease to provide a better all-round education than other schools they will die a natural death.

There was a time when some universities were in the same happy position as the public schools. As self-supporting institutions they could go their own autocratic way, impervious to outside criticism. They took special measures to encourage the influx of students of outstanding ability ; and as for the rest, the chief conditions of entry to a college were that they should be capable of paying highly for the privilege, and of passing a very elementary examination—often waived for men of noble birth or athletic renown. Those were the days when a headmaster is reported to have advised parents to send their sons to Oxford or Cambridge on the grounds that they would there make a number of very desirable acquaintances, and be kept out of mischief during a dangerous period of their lives.

The chief advantage of this complete independence was that it encouraged individuality in teachers and students ; the chief disadvantage of the many reforms that have taken place since then, resulting finally in financial dependence, is that they tend to discourage individuality. Is any university school of physics or chemistry, for instance, noticeably different from any other ? In London we do our best to encourage individuality by having different final examinations for certain degrees in different colleges; at the Imperial College the B.Sc. degree of London is awarded on the results of college examinations in which outside examiners take part. The advantage of this is that it is not necessary to bring our syllabuses and methods of teaching exactly into line with those of other London colleges. There is, however, a strong but fortunately not a majority body of opinion in the university in favour of common examinations, chiefly on the grounds that they are easier and cheaper to organise. I hope it will be long before our measure of independence disappears. I would go so far as to say that individuality, which should be a natural growth in universities, needs to be deliberately encouraged in these days of committee rule. Any step taken to discourage it is a step downwards.

Oxford and Cambridge still have considerable freedom of action, partly because of their old traditions, but mainly, I think, because of the financial independence of the colleges. I do not know how far the ancient universities of Scotland preserve their own complete independence, but, in spite of apparent autonomy, the newer universities of England have not quite the same measure of freedom as Oxford and Cambridge. Their income can normally only just cover their expenditure, for if the margin were

great, it would mean that they were receiving too much from the public. The close budgeting that is necessary inevitably restricts freedom of action. For instance, if the number of students be reduced, the loss in fee income may convert a slight surplus into a deficit for some years, as it is impossible to reduce expenditure on staff and equipment correspondingly quickly. On the other hand, the immediate effect of increasing the number is to make the balance sheet look healthier : until a strong case can be made for more expenditure on staff and buildings, which eventually results in increased cost to the public. It is unfortunate that there is quite a strong financial incentive to increase the number of students at universities ; it looks so well on paper. Yet I feel that the time has come when we ought seriously to consider whether a further increase can really be justified. The public, I take it, is not interested in the individual ; if the taxpayer thinks at all about his contribution to university education—and I do not suppose he does, as it is so trifling compared with other public calls upon his income—he must come to the conclusion that the object of his contribution is to help students who will subsequently be of more value to the nation if they spend three or more years of a sheltered existence at a university, than if they were obliged to earn their living on leaving school. Where shall we draw the line ?

There are many students who occasion no misgiving. They are those who are capable of teaching themselves, given the opportunity. To them, and ideally to all, the attitude of the university should be this : We give you here the opportunity of learning, if you wish to, from masters of their subjects ; we give you access to well-equipped libraries and laboratories ; and opportunities for learning from each other. We help you to help yourselves. What use you make of these opportunities depends upon yourselves. If we find you do not, or cannot, make good use of them, you shall go, and make room for others. Broadly speaking, I believe that is the right attitude. In such an atmosphere, learning, individuality, and self-reliance flourish ; and public expenditure is worth while. Judged from this standpoint, I have little hesitation in saying that universities are too full. As a result the tendency is towards over-organisation, too little latitude, and too much spoon-feeding. The more distinguished the teacher, the more he is tempted away from teaching and research : his presence is required on committees. In London we elderly gentlemen even organise students' athletics ; and official debates take place on such important questions as the site and finance of a university boat club for women. The wider we fling open the doors to a university, the more will such organisation be necessary, and the worse will be the conditions for the best teachers and students.

There is another, more practical, way of looking at this question of numbers. Do graduates find any difficulty in getting suitable employment at the end of their university career ? Perhaps it is hardly fair to attempt to draw a definite conclusion from experience during the last few years ; but it does form some guide to policy. The majority of students of the Imperial College enter some branch of industry ; and most of them, even in these difficult times, have succeeded in finding posts within six months of leaving the college. Whether they are all suitable posts for university

graduates, I doubt; many of them could equally well and perhaps better be filled by students from technical schools. I do not think this is an experience confined to the Imperial College; indeed, to judge from information I have had from other sources, I should say that we had been on the whole more fortunate than other similar institutions.

Different branches of industry seem to hold different views about the value of a university education in science. Compare, for example, the present position of the university chemist with that of the engineer. The chemical industry calls out for university graduates; every year you will find leading representatives of the prominent firms in the universities, looking for recruits. It is not demanded of the recruit that he should possess a large stock of practical knowledge; it is expected of him that he should have high scientific qualifications, and that he should have shown aptitude for independent work.[1] The attitude of the engineering industry seems different. In some branches of the engineering industry the university graduate is as welcome as he is in most branches of the chemical industry; but in many he seems to be regarded as a misfit. One prominent manufacturer, the creator of a great industry, who has lived most of his life near a university, has been known to boast that he employs no university graduates. Many employers seem to expect of an engineering graduate a degree of acquaintance with practice that they have no right to expect; for we do not pretend to teach at universities what can be better learned at the works. Finally my experience is that too many engineering graduates find themselves in blind alleys from which they have little opportunity to escape.

Where does the fault lie? With the employers or with the universities? I think there are faults on both sides: let me leave the faults of the employers for others to discuss, and for time to correct, and deal with some of the problems of university schools of engineering.

Engineering is a branch of technology. The object of a university school of technology is to seek to advance and apply scientific knowledge for practical purposes. Many people at universities still think there is something derogatory about this; they would prefer that instruction and research had no relation to the practical needs of mankind, forgetting perhaps that most if not all university education started with a practical aim in view, or we should have had no schools of law or medicine.

Let me quote from the report of the University Grants Committee for 1921: 'There is nothing in the nature of technology which makes it necessarily unsuited to the methods and spirit of university work. . . . The very fact that this alliance [between science and industry] is intimate, and the border line between pure and applied science difficult to define, involves serious difficulties for the universities. We cannot ignore a certain tendency to lay an exaggerated emphasis on utilitarian applications in

[1] In his Presidential Address to Section B in 1913 Prof. W. P. Wynne said:— 'Once again the cry has been raised in the press that chemists trained in our Universities are of little value in industrial pursuits; they are too academic; they are not worth their wage—little as that often is, whether judged by a labourer's hire or the cost of a University training.' Evidently some progress has been made!

some technological departments. . . . It would be in the worst interests of industry itself if the study of scientific problems were to be approached by the universities from the point of view of immediate material advantage. . . . We believe it to be urgently necessary, therefore, to define more closely the aim of university courses in engineering and technology, and to differentiate such courses from work properly assignable to technical colleges.'

With these views and criticisms, I heartily agree : what is more to the point, perhaps, is that they have, I feel sure, the approval of many university professors of engineering, who would say that their aim is to teach principles, not practice ; to train the mind without neglecting the training of the hand ; and to send out ultimately from the university resourceful men whose education and outlook enable them to attack with confidence the new problems that are perpetually arising in the engineering world. A university school of engineering should be primarily a school of what is now called classical physics, the principles of which are illustrated in lecture room and laboratory by examples and problems which have a special bearing on engineering. To a less extent it should be a school of mathematics and chemistry. I think we are inclined, at universities, to value too highly mathematical ability in an engineer. Many students have obtained first-class engineering degrees mainly through their mathematical ability ; but such students do not necessarily become first-class engineers, and some of the most original and distinguished engineers are poor mathematicians : one of whom I can think had to be content with a pass degree at his university.

I am inclined to think that there are too many students of engineering at universities. There are many young men who have a practical flair, but who cannot respond to the kind of teaching that I believe to be appropriate to the university. Their presence at the university, where everyone wishes to do their best for them, inevitably encourages the introduction of practical instruction of a kind more suited to technical schools. The university school is then trying to fulfil two functions, and runs the risk of failing to fulfil either well. Such men often have qualities which will carry them far in the engineering profession, which is large and varied enough to provide opportunities for men of very different types, but they are really out of place at universities, and would be well advised to take advantage of some of the excellent schemes now in operation for combined training at works and technical schools.

The same is true, I suggest, of other branches of technology. The chief aim of a university department of technology should be to produce the leaders of the profession. The best education for potential leaders is not the same as the best education for the rank and file. It cannot be expected that all university graduates will become leaders ; but at least we ought to look for, and develop, the qualities of leadership. This we cannot do if we fall into the temptation of mass production.

Highly specialised schools of science at universities present somewhat different problems. How many students, for example, should one encourage to study subjects such as mining geology, biochemistry, plant biology, entomology, when the demand for such specialists may be small

and fluctuating? Take the biological subjects as typical. Two years ago there was published the report of a strong committee appointed by the Government to advise on the education and supply of biologists. Their first two conclusions were:

(1) There is a substantial and growing demand from Government Departments for biologists for service in this country and in the colonies, and there is a small but probably growing demand for biologists from concerns engaged in agricultural production overseas and in industry in this country.

(2) It is not possible to state this demand in precise arithmetical terms, but the supply of candidates for biological posts is not equal to the present demand, and even in those branches where the supply is sufficient in quantity it is deficient in quality.

Whatever evidence in support of these conclusions existed when the Committee started its inquiry in 1930, I think it safe to say that even before the report was published these conclusions were falsified by events. The fact is that some ten to fifteen years ago there was a sudden demand for biologists to meet the needs of new and of rapidly expanding research organisations at home and in other parts of the Empire. Highly trained biologists of all kinds were sought for, and naturally could not be found in sufficient numbers, for universities cannot suddenly increase the rate of production of first-class specialists. Some of the new organisations made the mistake, therefore, of accepting less able and less highly trained men, which is bad for the individuals concerned and for the organisations; for, if a first-class man is really needed, it is better to wait until one is available than to make shift with a second-class man, who runs the serious risk of having his livelihood taken away from him later on.

Then came the world depression, and far from there being an increased demand for 'industrial' biologists in recent years, there has been a contraction. This is a serious state of affairs for universities. It would be a fatal policy to encourage young men of good ability to spend long years in specialised study, only to find at the end that there was no demand for their services, or that what little demand there was offered inadequate prospects for the future. It is a far better policy deliberately to keep the supply somewhat short of the demand; the world will not appreciably suffer if any particular application of science to industry and agriculture develops rather more slowly than the enthusiast could wish, and there are few spectacles more distressing than that of the highly educated specialist who is unemployed through no fault of his own, and whose training and interests do not fit him for other work. At the Imperial College we have ample room and equipment for more students of plant biology, plant biochemistry, industrial entomology and similar subjects; but we do not intend to fill the room until we can be more certain of the future. The lessons of the last few years teach us that public statements about the shortage of specialists in any branch of science and technology are apt to have an unfortunate effect in schools and in universities; for they may be out of date before a normal period of advanced training is finished.

It is of interest to examine a little further the Committee's belief that the supply of biologists at universities is lacking in quality as well as in

quantity, which they attribute to the neglect of biology as a subject of study in schools. While sympathising with their views, which are shared by many people, I think it cannot be denied that whereas a biologist must have an adequate knowledge of physics and chemistry, it is not necessary for a physicist or chemist to have a knowledge of biology ; and if one considers the position from a cultural rather than from a practical point of view, it would be fair to say that the boys who need least to study biology as a cultural subject at schools are those who are going to study it at a university. The only point that remains, then, is that if biology were taught more widely in schools it is possible that here and there a boy ' may experience from biology a pull which he had hitherto failed to secure from his special subject.' For my part I feel confident that directly there is an assurance of reasonable careers in biology, suitable candidates will be forthcoming, and education at schools and in the universities will develop on sound lines. Lack of teaching of biology at schools has not led to a shortage of doctors. How, then, can it be mainly responsible for a shortage of other biologists ? It needs no inspired prophet to foresee a great development some day of the biological sciences : the work of pioneers to-day makes that sufficiently obvious. The next generation may live to see a development comparable with that of the physical sciences, and their applications, in the last thirty years ; but the time is not yet ripe. Until it is, our duty at universities is to keep our biological departments moderate in size, but high in quality.

There is another consideration that one has to bear in mind in deciding how many students to encourage to specialise on any branch of science or technology. If the call for such specialists is small, it is clearly necessary to take into account what is being done at other universities. Universities are very human bodies ; if one institution makes a success of any particular new department, others will find a strong case to develop along similar lines. A little competition is healthy ; but the multiplication of specialised departments in different universities and colleges can easily be carried too far, resulting in an unnecessary waste of money. There are, for example, ten university schools of mining in Great Britain. This number can hardly be justified either by the demand for mining engineers at home, where there is little or no metalliferous mining, or by the demand overseas. In Germany, where there is a large metalliferous, as well as a large coal mining industry, there are only five schools of mining engineering of university rank. I feel that if the number of students were divided among fewer institutions the results would be better and the expenditure less. I do not suppose for a moment that anyone is likely to agree with me to the extent of abolishing any existing department, but I think we should learn a lesson from the past, and keep competition and local patriotism within reasonable bounds.

I have thought it worth while to put these practical considerations before you, although they are not exhaustive and do not lead to any definite conclusion on the problem of the size of university departments of science and technology. In the end the optimum size is a matter of judgment ; my judgment, for what it is worth, is that on the whole there is no strong case for increasing the numbers of students of science and

technology at universities. In thirty years' time this statement may look ridiculous, but one cannot foresee events so far ahead. Rather than any marked expansion in numbers should take place during the next five years, I should prefer to concentrate on giving the better man a better chance than he has now; to improve the quality rather than to increase the quantity.

It is commonly said of students of science that their general education is weak. The remarks of the committee on the education and supply of biologists may be taken as representative of a large body of critics, for they were based on the views of many witnesses.

'Among boys taking science as their special line of study there is too great concentration on science to the neglect of other subjects. Our witnesses view with anxiety the prospect of a growing race of illiterate scientists unable to express themselves adequately or intelligently in their own language, and ignorant alike of history and of the forces other than the chemical and physical which make the world in which they live.'

There is undoubtedly much force behind these criticisms; and yet I think the poor student of science is apt to be maligned. The great growth of knowledge in nearly every department of learning inevitably means that we all become more and more ignorant of each other's special interests; can it justly be argued that the young scientist who has little or no knowledge of history is more ignorant than the young historian who has no knowledge of science? Do we not, perhaps, tend to exaggerate the virtues of a general education, forgetting that many of the greatest men have had no education worth speaking of? I remind myself frequently, and particularly on this occasion, of the fate of Mr. Joseph Finsbury, of whom it is written that 'a taste for general information, not promptly checked, had soon begun to sap his manhood. There is no passion more debilitating to the mind,' the author adds, 'unless, perhaps, it be that itch of public speaking which it not infrequently accompanies or begets.' And if you know the book you will remember that one of Mr. Joseph's lectures 'to the great heart of the people' was entitled 'Education: its Aims, Objects, Purposes and Desirability.' I dare not continue the quotation.

At the Imperial College I have colleagues who have had over twenty-five years of experience of successions of boys from secondary schools. They say, without hesitation, that the standard of general education has increased steadily throughout that period. I am newer to the work; and when I reflect that so many of the present generation of secondary schoolboys who find their way to universities come from the poorest homes, I think the standard of general education is to be praised rather than decried. I think also that the man who has ideas of his own, and a capacity for doing something really well, is more useful and more interesting, even though he may be unable to express himself adequately in his own language, than one who is merely capable of describing other people's work and ideas in elegant English. When all these allowances are made, however, there is undoubtedly room for improvement. There are many scientific men

who write beautiful English ; and yet I suppose there is no gap in his equipment that the average scientific man deplores more in after-life than his difficulty in writing and speaking his own language well. I say this feelingly, as to me writing is a forced labour, and I am never satisfied with the result ; but with practice one can acquire a certain proficiency, and with the example of T. H. Huxley as an inspiration no one need altogether despair. My complaint of many young students of science to-day is not so much that they do not write clearly and concisely as that they do not seem to want to, which indicates insufficient practice and instruction at school to acquire a taste. Again, I should agree with the Committee that ' a competent knowledge of one modern language (French or German, the latter in particular) is, quite apart from its cultural value, an essential element in the equipment of the adequately trained scientist.' Much of the best scientific literature is written in German, and if a scientist cannot read German scientific papers, he is severely handicapped. At the Imperial College we found it necessary many years ago to institute special classes in German. It should not be necessary.

The schoolmaster is, however, in a quandary. There is a limited number of hours in the day, and if he taught all the subjects that he is advised to teach to all the boys—for everyone naturally thinks that his own special subject should form part of a liberal education—he would only succeed in producing a race of smatterers. He has to choose a happy mean between teaching more and more about less and less, or less and less about more and more ; and he not unjustly complains that during the last year of a clever boy's life at school he is hampered in his choice by the regulations and practice of universities. Schoolmasters at grant-aided secondary schools are in a special difficulty, for most of their pupils are not able to proceed to a university unless they win entrance scholarships. If university authorities complain that students are lacking in general education, it is for them to do their best, by altering the conditions of entry, or the standard of scholarships, to help schoolmasters to remedy the defects. I propose, therefore, to discuss briefly what changes are desirable. I shall base my remarks on the regulations of London University, and my own college in particular, but I think the regulations of other universities are sufficiently similar to make the discussion of general interest.

The first university examination is the Matriculation examination. A matriculation examination, I take it, was originally intended to be an examination the successful passing of which entitled a candidate to be admitted to the privileges of a university. The London University Matriculation examination has long ceased to be anything of the sort—at any rate, so far as students of science are concerned. It would seem more appropriate to regard it as an examination which entitles successful candidates to be admitted to the privilege of becoming bank clerks. Certainly few university schools of science will admit a student at the normal age of eighteen on the strength of his having passed the Matriculation examination ; some further proof of his proficiency is required. At the Imperial College we have a special entrance examination which mainly consists of papers in mathematics and science, but includes papers in English and a choice of foreign languages ; but I cannot say that a

candidate is refused admittance if he fails to do well in the English and Language papers, but does well in the other subjects.

The next university examination is the Intermediate examination. The original object of such an examination was to test the progress of a student in his special subject of study at a university, after he had given evidence of a sufficient general education at the normal age of entry. In fact, if we agree that a university is a place where students learn to teach themselves, under the guidance of distinguished teachers, instead of learning under the strict discipline of school, the main object of an intermediate examination should be to test a student's capacity to teach himself, and therefore to satisfy the authorities that he is fit to proceed with a course of study leading to a degree. Nowadays, as the Matriculation examination or its equivalent is passed by most intending students at the age of fifteen or sixteen, their remaining years at school are devoted to the special subjects of the Intermediate which many of them pass before they enter the university. They are encouraged to do so by university authorities. It saves us trouble, and gives the student time to acquire a larger stock of specialised knowledge in his undergraduate career. The next obvious step will be to take the degree examinations at schools, leaving the universities free to concentrate on postgraduate work !

While these changes have been taking place in school curricula, the standard of science entrance scholarships at universities has steadily risen ; and as most science scholarships go to boys who intend to study physics or chemistry at the university, the schools are encouraged—some would even say forced—against their will, to concentrate their advanced teaching on physics and chemistry. It is true that only a small proportion of the boys at any particular school intend to compete for scholarships, but it is impossible to segregate such boys altogether, and the standard of scholarship examinations, therefore, sets the pace for the higher school forms.

The object of a scholarship examination is to discover the boys of greatest promise, not the boys who have been most successfully crammed. I think that schoolmasters are inclined to attach too much importance to the character of the papers set, and to give too little credit to the examiners for intelligence. It is not always the boys who get the highest marks who win the scholarships, and it is not so very difficult for an intelligent examiner to distinguish between an active and a congested brain. At the same time, I do agree with the criticism that the papers set are usually too difficult. There is too great an element of luck about a hard paper ; and first-rate ability in a candidate is shown more by the way he answers a question than by his knowledge of detail. I remember giving practical effect to these opinions when I examined in the Final Honour School of Chemistry at Oxford fourteen years ago. One of the two papers I set in physical chemistry was so apparently easy, that I feel sure that a more cheerful group of candidates never sat in the Examination Schools. I am confident, too, that there never was an occasion when an examiner found it easier to distinguish between the relative merits of different candidates. The first-class man answered the questions briefly, accurately, and to the point ; the second-class man wrote pages of irrelevant matter, to impress the examiner ; and the third-class man made elementary mistakes.

It is not so easy as it may seem, however, to change the standard of scholarship examinations, and thereby to encourage a broader education. About a year ago we decided to review our policy at the Imperial College. Students come to the College with science scholarships from many sources ; but the chief sources are the Board of Education, who award Royal Scholarships tenable only at the College as well as State scholarships tenable at any university in England and Wales ; the London County Council ; and the College itself. For the past five years our scholarship examinations have been held in January at the suggestion of a group of headmasters of public schools, who advised that by doing so we should attract better candidates. We have not found this borne out by results ; we have not had enough good candidates in any year since the change to justify us in awarding the full number of scholarships ; and many of the better candidates have subsequently competed for and gained Royal Scholarships or State Scholarships which are higher in value. Our general experience leads us to believe that very few, if any, students of first-rate ability, who have specialised in science at school, are prevented from going to a university for lack of financial assistance. On the other hand, we believe that no scholarships are deliberately made available to assist able students who have not specialised in science at school to study science at a university. We have therefore decided to make the experiment of changing the character of our January scholarship examination. We propose to set papers in General Science and Mathematics of quite a low standard, together with papers of a higher standard in History, Foreign Languages and English. The details are not yet settled; but headmasters and headmistresses were notified of the change this year, and their criticism and co-operation were invited. The scheme has had a mixed reception. We have received many encouraging, but many critical letters. Much of the criticism can be summed up by the phrase, actually used—'It would not suit my Sixth, and I should not alter my Sixth to suit it.' Now schoolmasters cannot have it both ways ; they cannot say, on the one hand, that they are forced to specialise unduly at schools by the standard set by examiners for science scholarships, and, on the other hand, that they do not propose to make any change if university authorities listen to their criticisms. We intend to go on with the experiment, without any great hopes of the result ; someone must make a start, and the most unpromising experiments have often given surprisingly good results. At the same time, I fully realise that what one particular college does cannot solve the difficulties of the schools. If it is really the general view that the school education of a student of science is too narrow, then the best practical step is to reform the University Matriculation examination, and make it appropriate to the normal age of entry. If one of the larger universities did this, the effect would be considerable. If it is not considered worth while, then criticism of the general education of the science student loses most of its point.

I have put before you some problems of the present ; I want now, before I conclude, to touch briefly on a problem of the future.

All university education in science and technology is designed primarily to produce teachers or professional scientists or technicians. Most engineering students intend to become practising engineers; most chemists who do not enter the teaching profession become research chemists or chemical engineers; most students of biology become doctors or professional biologists. A few graduates in science break adrift, and turn with success to other occupations: to the law, for example, to general administration, or even to literature! Of His Majesty's present Ministers, one took a degree in biology at a Scottish university, and another a degree in chemistry at an English university. But these are rare exceptions; most science graduates are specialists skilled in a particular branch of science, and ignorant of other branches. A hundred years ago it was not difficult for a scientific man to follow in detail the work of others; now it is as much as a specialist can do to keep abreast of the progress of knowledge in the particular field in which he is interested. No one studies science at a university as a general education, as men study classics, philosophy, and history; indeed no one can, for no university supplies the opportunity. 'Modern Greats' at Oxford includes the study of history, economics, philosophy and 'the structure of modern society,' but not of science!

During the present century there has been a struggle to secure a wider recognition of the value of scientific study and research, not only for the advancement of knowledge, but for the progress of civilisation. Now that this recognition is widespread; now that we all see plainly the great influence of scientific discovery on social developments; now that specialised departments of science are flourishing at universities; surely an effort should be made to provide for men who have no desire to become specialists, but who wish to study the broad principles and applications of science, for their own education, and as the best preparation for after-life in many spheres of human activity. The place of the specialist in industry and in the machinery of Government is assured. Large establishments have grown up, mushroom-like, to meet the demand for industrial research. Biological research is also gaining recognition, but more slowly, for public opinion has not yet been educated to the point of realising that, in the long run, it would be fatal to attach more value to industrial research than to applied biology. With all this increase of scientific activity, there has arisen an urgent need for skilled administrators and men in public life who have a real knowledge of the principles and methods of science; not the kind of knowledge that is derived from conversation, listening to broadcast talks, and reading popular books, however good these may be, but that which is gained by serious study. We cannot complain that there are few such men among the present generation; it is a great thing that there has been a change of attitude of mind. But unless something is done, there will be no greater number in the next generation.

Is the time ripe for action on the part of the universities? I think it is. The great accession of knowledge in all branches of science may often seem bewildering; but its effect has been to make the main principles clearer, and easier to teach, for a connecting thread runs through them.

The foundations of science have been laid; they will be strengthened in the future, but it is unlikely that they will be rebuilt. The structure that is built on them grows ever more coherent; it can be studied as a whole, without examining in great detail any of its parts. The subjects of the university school I have in mind will include the study of the foundations and philosophical background of science; of its history; of the history of social development; of the applications of science to industry, agriculture and medicine; of problems of population and health—and the like. The student will learn that law and order in the universe is not a faith but a reality; and that science is 'nothing but trained and organised common sense.' He will learn too, I hope, to acquire the spirit of that unprejudiced search for truth which is the basis of all fruitful scientific inquiry.

These are but vague suggestions; the practical thing to do is to make a start; and the best way to make a start is to select the right man to direct such a school—and there are men available—to put him in the right environment, and to give him the opportunity to work out his own ideas. That good would result I have not the slightest doubt.

SECTION M.—AGRICULTURE.

SCIENTIFIC PROGRESS AND ECONOMIC PLANNING IN RELATION TO AGRICULTURE AND RURAL LIFE

ADDRESS BY

PROF. J. A. S. WATSON, M.A.,

PRESIDENT OF THE SECTION.

Ever since the beginnings of civilisation the rate of improvement in agricultural technique has controlled and conditioned, to a considerable degree, the progress of the human race. This progress has been of two kinds—on the one hand an increase of numbers, and on the other a rise in the standard of life.

At certain times and places better farming has meant no more than the possibility of a given level of subsistence for an increasing number of people. Indeed, where the available land has been limited, where conditions of climate and the like have favoured the increase of population and where the progress of agriculture has been relatively slow, we find all the essential features of that rather gloomy picture of man's economic destiny which Malthus conceived as normal. Broadly speaking, this has been the state of things, in China, during many centuries. Conditions among the Western nations have, however, become more and more unlike those that Malthus presupposed. He assumed that populations tend to increase in geometric progression, whereas in many countries population is already, or is rapidly tending to become, static. He assumed that the additional land, brought under cultivation in order to meet man's growing necessities, would be inferior in some respect to that already farmed; but at present the tendency upon the whole is for farm land to go out of cultivation. Malthus could foresee no more than a slow and dwindling rate of increase in the productivity of the soil, each successive increment being obtained at the cost of a progressively greater amount of human toil; but recent additions to scientific knowledge have been enough to outweigh the effects of the economists' law of diminishing returns; our increasing output of food is being secured with less and less toil, instead of more and more. The main result of the most recent agricultural progress in the more advanced countries has been then to set free, for activities other than food production, an increasing proportion of the population, with, as a secondary consequence, the possibility of an unprecedented rise in standards of life.

Before, however, we attempt to analyse the present situation of our

industry, or try to predict its future, it may be well to cast our eyes back over some of the main stages in its evolution. This is the easier to do because on each of the main steps of the ladder some part of the human race has been left standing—providing a living relic of what was once perhaps the most advanced type of economic life.

We have indeed—in Australia, in Ceylon, in Africa and elsewhere (and often under conditions quite favourable to agriculture)—remnants of those peoples who refused to become either tillers of the soil like Cain, or keepers of sheep like Abel. With them—women and children as well as men—life consists of an unremitting food-quest. Their dietary includes articles like grass seeds, insect grubs, mice and snakes, yet they are often reduced to hunger and famine. They must wander over wide areas to secure their meagre fare and they have neither time nor energy to spare for the arts of civilisation. It is worth noting that their fundamental disability is a lack neither of intelligence nor of manual dexterity, but of foresight. They cannot see beyond their immediate necessities. They will work for a daily wage but not for a yearly harvest. The Bushment of South-West Africa, for example, can be trained to become capable herdsmen, but they never become independent stock-farmers because they cannot resist the temptation to kill when they are hungry.

When men first began clearly to anticipate their material needs, and to plan ahead in order that these might be supplied, they naturally strove to bring under control those species of plants or animals on which, in their earlier unplanned economy, they had been accustomed to rely. Thus the big-game hunters of the Asiatic plains became, in course of generations, nomadic herdsmen. In the flood valleys of the Nile and Euphrates unaided nature solved what has elsewhere been the chief problem of the cultivator—the maintenance of the fertility of the soil—and there the greatest of our early civilisations were founded upon an assured supply of corn. But the herdsmen who have become nothing more have condemned themselves to a very limited and an insecure existence. They may build up immense capital in the form of live stock, but they still live in tents and subsist entirely on meat and milk or, like the Massai, on blood and milk ; and a drought or an epidemic of stock disease may reduce them, in a few weeks, from a state of plenty to one of famine.

Again the cultivators who have clung to plant life alone as a means of sustenance maintain, except in specially favourable localities, but an inconclusive war with nature. On the one hand, the maintenance of soil fertility without animal manure has been usually, until the recent introduction of other fertilisers, a nearly insoluble problem ; hence land, becoming exhausted after a few years of tillage, has had to be again abandoned until such time as natural processes should restore its fertility. The periodic clearing of new areas, added to the routine operations of tillage and both carried out by means of primitive hand tools, give a very real meaning to the curse of Cain. Finally, a purely vegetable diet, often restricted to one or two specially productive plants, may be not only monotonous but seriously deficient in nutritive value.

The contriving of a system of mixed farming, embracing both plants and animals, was a remarkable stage in the progress of civilisation. It

has been surmised that it came about through the conquest of the cultivator peoples of Egypt and Mesopotamia by herdsmen peoples from the north-east. The combination did many things. It made possible the application of animal power to the soil. It enabled permanent agriculture to replace shifting cultivation. It provided at once greater abundance, more variety and greater security in the food supply. It enabled men to fix their abodes and thus made worth while the building of permanent dwellings and the accumulating of household goods. It set free human energy for the arts of civilisation. In short, it enabled the men who devised it to inherit the earth.

But life for these innovators became not only fuller but also more complicated. Man had to organise the food supply not only of his family but also of his beasts, and to this end he had to bring under cultivation new species of plants and invent new methods of fodder conservation. As the mixed farmers spread over the world they had continually to exercise their ingenuity in adapting their system to the varying natural conditions of their new homes.

This system was improved and modified during ancient and medieval times without undergoing any fundamental change. There was a minor hiving off of other industries from farming and a consequent growth of trade; there were some temporary experiments in the mass production of food, especially by the Romans and by means of slave labour. But up till the time of the industrial revolution the typical citizen of the civilised world was the family farmer, looking to his own land to supply the bulk of his material needs and producing but little for sale. He remains to-day the typical citizen of many great and populous countries, and his class is easily the most numerous in the world.

But the eighteenth century saw the beginnings of another great change. Primarily this had little to do with the business of growing food or other farm produce. It concerned what had hitherto been but minor industries, occupying the time of the farmer and his wife in winter evenings or employing a few village craftsmen—industries like the spinning of yarn and the weaving of cloth, the fashioning of ploughshares and of cart wheels. The successful application of mechanical power to these manufacturers meant their removal to convenient sources of power and, therefore, their removal from the farm. The separation of agriculture from other industries meant an increase in the exchange of goods, and this necessitated, in turn, the provision of improved means of transport and a great increase in the supply of money and credit.

The agricultural changes which accompanied the industrial revolution were changes of organisation rather than of technique. There was (with the possible exception of Meikle's threshing machine) no new agricultural invention comparable to the spinning mule, the power loom, the new blast furnace or the steamship. The successful application of mechanical power to the soil was not to be achieved for another hundred years. But farmers had to replan their industry with their eyes upon a market rather than upon their own personal requirements. This favoured a degree of specialisation in production that had hitherto been impossible. It favoured a larger type of enterprise and led to the engrossing of farms.

Because of the disappearance of the old fill-time home industries it necessitated a replanning of farm work. It required, of course, the investment of fresh capital, and thus gave the whip hand, within the industry, to those individuals with capital to command.

The revolution was not carried through without a good deal of hardship to individuals—some of which, according to modern standards, amounted to grave social injustice. The enclosures of the old open-field villages of the English Midlands and the Highland clearances need only be mentioned in this connection.

Indeed, there have been difficulties and hardships associated with all the major steps of progress that we have traced. Each departure from tradition required a fresh effort of will and made a new demand for courage and enterprise. At every stage there were people who thought that things were very well as they had been; but these people have always been wrong. No reasonable interpretation of history can leave us in doubt that each great step in economic evolution has been amply justified. It is not only that a higher level of material prosperity has been attained, but that, upon the whole, this material prosperity has been turned by men to good account. No reasonable person would wish to return to the life of the Australian aborigine, the nomad or the African cultivator upon his patch of maize and yams. Many people feel, indeed, a strong if rather sentimental attraction towards the old peasant way of life. This is easy to understand, for most of us are removed but a generation or two from peasant homes. In truth, the modern business farm suffers, in some ways, by comparison with the peasant holding; but only, as I believe, because we have not as yet fully succeeded in translating the economic advantages of the former into social good. The broad lesson of history, as I see it, is that we must take our courage in both hands and face the task that we now see before us.

For some of the origins of our present agricultural problem we must go back to the seventies of last century, which marked the end of what has been called the golden age of British farming. At that time, in those countries where agriculture had been separated from the other industries, the division of national incomes between the two classes was favourable to the agriculturist—he got fair value, in terms of manufactured goods and services, for his labour and enterprise. It is true, indeed, that where the agricultural class was divided into landlords, tenants and labourers there was, according to modern standards, a very inequitable division, as between rent, profit and wages, of the net gains from farming; but this inequity was by no means peculiar to farming.

Since the seventies the productive capacity of agriculture has constantly tended to increase more rapidly than the demand for agricultural produce. The one check in the process was caused by the Great War, but this has already been more than made good. The result has been that, except during the period from 1917 till 1921, when the boot was certainly on the other leg, agriculturists have failed to secure a due reward for their increasing efficiency.

The rise in the output of world agriculture has been made possible, firstly, by a vast increase in the area of available land, and in supplies of

the farmer's other primary raw materials. The process of expansion began with the opening up of the North American prairie for corn growing, following the building of railways and the invention of the binder. At first it was confidently predicted that the flood of corn would be only temporary, since a few years of 'prairie farming' must exhaust the most fertile soil in the world. But the prairie soil was found to be different stuff from that of Western Europe, and its exhaustion proved to be a vain hope, or a groundless fear, according to the point of view. Moreover, one new country after another went through the process of agricultural development, and the problem of transport was solved not only for corn and wool, but also for meat, dairy produce, fruit and, indeed, for every commodity except the most bulky or the extremely perishable. But it is not only transport developments that have thrown open new fields to the farmer. Irrigation schemes and dry-farming technique have added great areas of what was formerly desert. Plant breeders, by producing quick-maturing strains of plants, have extended the northern limits of cultivation by a belt that embraces hundreds of millions of acres. The growing control of human and animal disease is creating the possibility of settlement and agricultural development over vast areas of the tropics which, as yet, have been hardly touched. Thus the old fear of overpopulation, which has coloured so much of past economic thought, has been removed to a distance that now seems incalculably far.

Apart from land, the most important of the farmer's primary raw materials are fertilisers, and here it is enough to say there can be no anxiety about future supplies. The crisis in connection with the supply of nitrogen, which seemed thirty years ago to be approaching fast, has been completely averted. Nitrogen is now available to the farmer, in infinite quantity, at less than half its pre-war price.

The other cause of the growing abundance of agricultural produce has been, of course, the application of the rapidly increasing body of scientific knowledge to the business of plant and animal production. I do not propose to weary you with a catalogue of recent advances in agricultural science, or to show how these have been translated by the farmer into improvements in practice. Two or three examples must suffice. The latest report on the Agricultural Output of England and Wales shows that (through the application of the sciences of genetics and nutrition) the average output of eggs, per bird, increased by 20 per cent. in six years. The use of the tractor and the combine harvester enables a reduction, in the labour cost of corn production, of more than 50 per cent. The output of meat, per acre of grassland, has been increased, at Cockle Park and on much similar land elsewhere, by more than 100 per cent., through the use of what was once a worthless by-product of our steel industry. A simple and cheap remedy has been found, almost the other day, for the 'rot' in sheep which has often in the past killed a million sheep and more in a single year. And so on—more farm land and more fertilisers, more machines and more science, all leading to the same result of cheaper, easier and more abundant production.

I am not suggesting that overproduction is the sole cause of the

present crisis in world agriculture. Indeed, the immediate cause is the fall in the general price level following the contraction of currency. But a tremendous fall in prices, due to the same cause, occurred at the end of the Napoleonic wars without causing the general ruination of agriculturists. The severity of the present crisis has been due, as I see the matter, to the preceding long period of inadequate returns in agriculture, which left the industry with depleted capital and a burden of debt, and therefore unfit to withstand a period of general economic disorganisation. If the significance of rapid agricultural progress had been realised in time, and if nations had been prepared to accept its logical consequences, there might have been no necessity to-day to devise any revolutionary economic plan for the industry. For instance, it might have been foreseen that the cheap producer in the new countries must displace the dear producer in the old, and that as Canadian prairie was broken up, Midland clays must go down to grass. But no country was prepared to accept either a decline in the number of its agriculturists or a reduction of its home output of food. Rural depopulation was viewed with widespread alarm, and the extensification of farming was regarded as an evil implying almost moral turpitude on the part of the farmer. Again it might have been seen that, the world's requirements of bread being amply met, some of the surplus energies of farmers might have been diverted to the production of more interesting commodities like fruit or chickens or tobacco. But States, when they intervened at all, did so in the opposite sense—encouraging the production of the old necessaries and discouraging the expansion of consumption of luxuries. Such ideas die hard. It is still considered a meritorious thing to employ an agricultural labourer, but there is no particular feeling about the employment of barbers, haberdashers or electricians. It is somehow more honourable to plough a field than to let it lie in grass. It is a nobler thing to grow wheat (even if nobody wants to eat it) than peaches or strawberries. These notions are a legacy from the time when the world was hungry of necessity, and when people lived healthily in the country but died quickly in the towns. We must realise that these conditions have ceased to be. There is a superabundant organisation for food production, and there is no difficulty about breeding up a good and healthy human stock in the modern city. It seems to me that there is no argument for keeping unnecessary workers in agriculture or for driving people back to the land.

During the past few years there has been a rapidly growing realisation, in one country after another, that the farmer's economic lot was becoming unendurable, and a mass of different expedients have been devised, either by governments themselves or with their sanction and approval, to ensure something like a fair price for agricultural commodities. These measures are based on a wide variety of principles, and some are open to obvious criticism. For example, we have compulsory restriction of output; monetary compensations by the State for restrictions voluntarily made; even plans for the destruction of produce which is judged to be in excess of demand. We have direct State subsidies designed to make good the difference between cost of production and market price:

the fixing of internal prices by the State, combined with State control of imports and exports; export subsidies; tariffs designed to raise prices to a desired level; restriction of imports, with or without tariffs, intended to adjust supply to demand. The list is by no means complete. Some of these measures, indeed, are not so much rational means to assist agriculture as the weapons of economic warfare, in which apparently one of the objects of strategy is to force upon the enemy more food than he can eat.

It is perhaps necessary then to restate the fundamental (and essentially very simple) ideas upon which any real scheme of economic planning must be based. In the first place, successful planning necessitates the accurate prediction of demand and implies an undertaking, on the part of producers, to deliver the quantity of goods required. In the second place, it involves the fixing of a price for the commodity in question which will allow the producer a reasonable, and no more than a reasonable, reward, and only provided that (1) his technical methods and general management are reasonably efficient, and (2) the natural conditions and economic situation of his farm are reasonably favourable to the production of the said commodity.

That the translation of these ideas into practice must be a hard task is obvious. Demand is not static, but is subject both to long-term changes and to temporary fluctuations, due in part to causes that are some of them accidental and some of them obscure. Planning must anticipate an increase of consumption demand, and indeed endeavour to stimulate it. Again, agricultural production is still subject to the accident of drought, epidemic disease and so forth. The determination of farming costs on which, under a planned economy, prices must be based is beset with rather special difficulties. Some people feel that these objections to planning are insuperable, and that the system presupposes a measure of understanding between one producer and another, between exporting and importing countries and between producer and consumer, that is quite beyond the bounds of reasonable expectation. Indeed, if the crisis had been less urgent, the institution of our marketing schemes should have been preceded by a period of research, experiment and education.

One must protest most strongly against any notion that economic planning is a panacea for all our ills or is any substitute for education and research. The main lesson of the Russian plan for agriculture is not, as I see it, that the basic ideas behind it were wrong—I believe they are essentially right—but that their translation into practice necessitated an increase of scientific knowledge and technical skill, and a change of economic and social outlook that could not be attained at the rate which the plan contemplated. There is a risk, I believe, that we shall fall into the same error and suffer some of the same consequences. Another danger inherent in planning is that it may be used primarily to further narrow national ends, thus becoming only another weapon in the armoury of economic war. It is easy to see how it might be used, in this country, with the chief objects of increasing our agricultural area merely at the expense of that of other countries; of increasing our home production

of food merely by causing a reduction elsewhere ; of finding jobs for our unemployed by throwing overseas producers out of work. It is, of course, true that scientific and industrial progress is making countries, in some respects, less dependent one upon another. Italy, by developing her water power, has reduced her need of our coal ; we, by building Billingham Works, have lessened our requirements for Chilean nitrate. Some increase of self-sufficiency is the inevitable consequence of progress. But it is still true that civilised countries depend largely—for the abundance, variety and security of their food supplies, as well as for many other material blessings—upon a free and large international exchange of goods. World trade has shrunk because our monetary system has been unequal to the task of maintaining its flow. People are idle because they cannot exchange, one with another, the things which they might produce. Mere one-sided restrictions on trade can form no part of any sane plan. International trade agreements, indeed, are an essential part of any scheme.

Supposing that the marketing schemes succeed in restoring a level of moderate profitability to agriculture, there will still remain the considerable task of reconditioning our farms. Apart from the period of two or three years at the end of the war there has been no business inducement, for more than half a century, to put fresh capital into farming. Many of our existing buildings were planned at a time when wages were at less than a third of the present rates, and therefore with little regard to economy of labour. Some farms are of an uneconomic size in relation to modern kinds of equipment. There are heavy arrears in the matter of plant and machinery renewals, of drainage and liming. There is also, in many cases, a heavy burden of debt.

In some countries the problem of farmer indebtedness is so acute that it has been thought expedient for the State to intervene, e.g. by prohibiting mortgage foreclosures, by proclaiming moratoria on mortgage interest, or by making or guaranteeing loans at specially low rates of interest. These measures have become necessary because the long-continued underpayment of agriculturists has led to the severe depletion of agricultural capital, but in themselves they can provide no permanent solution of the farmer's economic problem, which is one of prices. It would seem that the recapitalisation of the industry could be most quickly brought about by the deliberate raising of prices, for a short period, somewhat above the 'fair' level as previously defined. The profits made would undoubtedly be largely reinvested in farming, and new capital would be attracted. Moreover, after a long period of under-payment, a short period of over-payment is no more than the farmer's due.

Reorganisation presents the greatest difficulties in the case of those branches of the industry which, so far as can be foreseen, must suffer a permanent reduction of demand for their products. A case in point is the production of oats which has been from immemorial times one of the main departments of farming in this part of Britain. The general rise in the standard of living is causing a general decline in the use of oats for human food, and the substitution of mechanical for horse transport is gradually killing the alternative market. For other purposes,

such as cattle feeding, or the manufacture of starch, etc., there are many competing commodities, such as maize, which are less costly to produce. The case of the northern farmer has a good deal in common with that of the Lancashire cotton spinner—both are suffering from the general depression, but also from a special decline in demand for their particular products. The permanent solution must be gradually to replace the oat crop by some other ; and State assistance to this end would be of greater ultimate benefit to the industry than a subsidy or other device to make oat growing again profitable.

Let me conclude by trying to draw a picture of the changes in farming and in rural life that would be both desirable and possible in a world where the principle of a fair price was permanently established, and where agriculturists would fairly share the benefits from any future improvement in their efficiency as producers. I cannot, as I have already said, foresee any large increase in the numbers of people employed on British farms, or any large schemes of land reclamation which would add materially to our agricultural area. These things can be achieved only at a real and considerable cost to the consumer, for they would imply a displacement of cheap production overseas by relatively dear production at home.

What one can foresee is the rapid spread of a variety of measures of reorganisation calculated to increase the output per unit of labour. Seventy years ago the rent of the land was usually, and by far, the largest single item of the farmer's expenditure ; ordinary farm land might pay a rent of three pounds an acre, while wages were ten shillings a week ; the landlord's share of the net output might easily be twice that of labour. Hence the chief objective in farming was economy of land—high output per acre. Now that land is abundant and rent a comparatively small fraction of expenditure, the chief object must be economy of labour.

There is indeed already a growing tendency to fit the land and the capital to the man rather than the man and capital to the land. This is implied in the use of the word *unit*, which is becoming so common, for example, in relation to pig, dairy and poultry enterprises. The unit is a department designed with the primary end of providing the optimum amount of work for a whole-time skilled specialist, with or without a limited amount of less skilled or partially trained labour. The man is equipped with a labour-saving device whenever this will make possible an economic increase in his output, and his functions become, to an ever-increasing extent, mental in character.

This kind of change must obviously tend towards an increase in the size of individual departments on the farm—one thinks, for example, of one-man units of 300 pigs or 2,000 head of poultry, or of two-men dairy units of sixty or seventy cows—and hence it must often imply either an increase in the size of the farm or, alternatively, some degree of simplification and specialisation of its organisation. This simplification, together with a growing tendency to delegate management to heads of departments, may be expected to reduce management as well as labour costs. Moreover a great part of the function of management in the past has been marketing, and the development of the marketing schemes may be expected greatly to reduce this side of the work. A 'clean-boot' farmer on three or

four hundred acres of ordinary land will no longer be able to justify his existence.

The carrying out of this kind of reorganisation demands a new standard both of general and of technical education in the farm worker. Indeed, the provision of short courses of instruction for specialist workers—in pig-keeping, milk production, tractor work and the like—is an urgent need. The cash value of skill and knowledge must grow with the increasing responsibility of the worker.

I well know that the whole idea of ' factory farming '—the growth of machinery and the specialisation of labour—is repugnant to many people. The variety of occupations on the one-man mixed farm, the pride of individual ownership and so forth are held to compensate for unconscionable hours of labour and small returns. But I have never been able to see that inhuman personal relationships need necessarily go with specialised occupations, short hours and high wages. Indeed I believe that, on the factory farm, it is possible to cultivate a kind of team spirit which is essentially a finer thing than the rather narrow independence of the small-holder. In any case, the greatest obstacles to a richer and fuller country life have always been poverty and lack of leisure. If we can remove these obstacles we shall have done much.

REPORTS ON THE STATE OF SCIENCE,

Etc.

SEISMOLOGICAL INVESTIGATIONS.

Thirty-ninth Report of Committee (Dr. F. J. W. Whipple, *Chairman*; Mr. J. J. Shaw, C.B.E., *Secretary*; Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. C. Vernon Boys, F.R.S., Sir F. W. Dyson, K.B.E., F.R.S., Dr. Wilfred Hall, Dr. H. Jeffreys, F.R.S., Sir H. Lamb, F.R.S., Mr. A. W. Lee, Prof. H. M. Macdonald, F.R.S., Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., F.R.S., Rev. J. P. Rowland, S.J., Mr. D. H. Sadler, Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Dr. H. Shaw, Sir Frank E. Smith, K.C.B., C.B.E., Sec.R.S., Dr. R. Stoneley, Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S.).

Organisation.—The first care of this Committee has for many years been the maintenance of the International Seismological Summary, and it was with great satisfaction that the Committee learned in the autumn of 1933 that the University of Oxford had agreed to house and pay part of the operating expenses of the I.S.S. for such time as the remaining costs of the Summary were met from sources outside the University. The Committee decided that the balance in the general account on June 30, 1933, should be transferred to the Observatory. A sum of £75 received under the terms of the will of the late Dr. J. Crombie was transferred at the same time. Further, the grant of £100 from the Caird Fund of the British Association was allotted to the Observatory.

The financial arrangements for the International Seismological Summary were the subject of much discussion at the Lisbon meeting of the Seismological Association of the International Union for Geodesy and Geophysics. A special grant equivalent to £150 was made by the Association and the need for additional assistance was brought to the notice of the Union. The Bureau of the Union is now fully aware of the situation and it is hoped will be able to give liberal assistance. To provide, however, for the work of the next two years up to the next meeting of the Union the help of the British Association is required. The Committee is allotting £100 from the Gray-Milne Fund and submits an application for a like sum from the Association, i.e., for grants of £50 for two years.

In 1933 the honorary degree of M.A. was conferred by the University of Oxford on Miss E. F. Bellamy in recognition of her valuable services to Astronomy and Seismology. Congratulations will be offered by seismologists in all parts of the world, who have good reason to appreciate the efficiency of the staff of the University Observatory.

Travel times of earthquake waves.—The work summarised by Messrs. Jeffreys and Bullen in the last Report on the travel times of earthquake waves was communicated by Dr. Jeffreys to the International Seismological Association and will be published shortly by the Association, part of the

cost being borne by this Committee. At the request of Prof. Plaskett the Committee considered the question what tables should be used in the International Summary for 1930 and subsequent years and recommended the adoption of the new Jeffreys-Bullen Tables. It is anticipated that the utility of the Summary will be greatly increased, not only by higher accuracy in the determination of epicentres but also by the facilities for comparing the times of passage of waves from an individual earthquake with the standard times.

It may be recalled that Prof. Turner regarded the accumulation of material for providing standard tables as one of the objects of the Summary and that in his last Presidential Address to the International Seismological Association he expressed the hope that new tables would be available for use in the 1930 Summary.

Mr. J. S. Hughes has kindly prepared the following statement as to the present state of work on the Summary.

International Seismological Summary.—The preparation of the third quarter of 1930 is well in hand. Delay has been inevitable owing to the necessity of awaiting the decision of the Seismology section of the International Geophysical and Geodetic Union at Lisbon, and from other causes, but at present the work is going forward at a satisfactory rate, in spite of the increasing number of observing stations now sending to Oxford.

Beginning with 1930, certain modifications have been introduced. The arrangement of the printing has been slightly altered in the interest of clarity and the method of making determinations has been revised so as to depend almost entirely on the P phases when these are available. Throughout the work the new tables by Dr. Jeffreys and Mr. Bullen have been used. These are a revised form of Dr. Jeffreys's earlier work, 'Tables of the Times of Transmission of the P and S waves of Earthquakes,' 1932.

The Introduction to the Summary for the year 1930 contains an account of the alterations made and also the Bullen-Jeffreys travel-times for all the phases tabulated. These are P, S, PP, SS, PcP, ScS, PS, PKP, PKS, SKS, PKP_2, SKKS, SKSP. Residuals for the phases P, PcP, PKP, PKP_2 and S, ScS, SKS, SKKS may now appear in the columns headed '$O-C$' (observed minus calculated) instead of just P, PKP and S, SKS.

The Constants of Seismological Observatories. As a preliminary to the work on the travel times of seismic waves Mr. K. E. Bullen calculated the constants of about 350 seismological observatories. These constants are used as Cartesian co-ordinates but are actually the direction cosines of the vertical at each point. The table of constants has been published by the British Association during the year.

The importance of the distinction between Cartesian Co-ordinates and direction cosines has recently been emphasised by the discussion in a paper by B. Gutenburg and C. F. Richter of the 'Advantages of using geocentric latitude in calculating distances.' It may be that the time is approaching when the spheroidal form of the earth will have to be taken into account in estimating all the distances used in detailed seismological investigations.

Seismographs.—The Milne-Shaw seismographs belonging to the British Association have remained in operation at Oxford, Edinburgh, Perth (West Australia) and Cape Town.

The seismograph which had been in operation at the Royal Observatory, Cape Town, was transferred in 1931 to the University a few miles away, the new site being much less subject to change of level and to disturbance by wind. Prof. Alexander Brown, who had accepted the custody of this instrument was impressed by the need for records of both horizontal com-

ponents of the earth's motion, and during his visit to England in the autumn of 1933 it was arranged that, in view of the importance of the station, a second seismograph should be provided by the Committee. This instrument was supplied in May of this year.

The attention of the Committee has been called to the desirability of a seismograph record in the island of Jersey, which is situated in a region where small earthquakes have been comparatively frequent in recent years. It was hoped that arrangements could be made for the installation at St. Louis Observatory, Jersey, of a Mainka Seismograph placed at the disposal of the Committee by Dr. Crombie's executors, but this has not proved practicable. The Committee is indebted, however, to the governing body of St. Louis Observatory, Jersey, for the consideration given to this matter.

The Science Museum at South Kensington possesses an excellent collection of seismographs. A valuable addition to the collection is to be made shortly, a seismograph which will be kept in operation in view of the public. The records of this instrument will be on smoked paper, and there will be an alarm bell to give audible warning when an earthquake is being recorded. Mr. J. J. Shaw is providing this installation and expects to have it in operation during the autumn.

At Kew Observatory, where three Galitzin seismographs are in operation, an additional instrument has been taken into use. This is a reproduction of the Wood-Anderson torsion seismograph which has proved of great value in America for the study of near earthquakes. The special feature of this seismograph is the minute moving system. It was suggested in 1913 by G. W. Walker that a seismograph might be made to go in a tumbler. This ideal has almost been reached in the Wood-Anderson seismograph; the base of the case containing the moving system is only 5 ins. square and the height 12½ ins. The efficiency of the instrument may be judged by the fact that it recorded, on January 1, 1934, an earthquake near Biarritz which was not shown on the Galitzin records.

The Great Earthquake in India.—Amongst the earthquakes of the year, by far the most important is the one which occurred on January 15, 1934, in the north of India near the frontier between the Province of Bihar and the Native State of Nepal. To judge by the distance at which this earthquake was felt, about 1,000 miles, it was one of the greatest on record. In the central area about 140 miles long and 90 miles wide, twelve towns with populations from 10,000 to 60,000 were completely wrecked, and there was great destruction of property over an area as large as Great Britain. In the circumstances it is remarkable that the estimated death roll in Bihar did not much exceed 7,000. This is attributed to the majority of the population living in low-roofed mud huts which, even when they collapsed, caused little injury. Large tracts of agricultural land were ruined by the coarse sand ejected from fissures and blowholes in the surface.

The following graphic account of his experiences during the earthquake was written by Dr. V. D. Wyborn at Ord, 25 miles south of Darjeeling:

'About 2.30 P.M. a sudden trembling of the ground started, accompanied by a rumble as of distant thunder. Trembling was steady for about 3 minutes. Character of a rhythmic vibration about 2 beats per second (very much resembling that felt in a motor launch having a very vibratory or loose bearing petrol engine). The brick and steel reinforced house shook and rocked visibly and appeared as if it would collapse. Bottles shook and fell. Walls cracked and plaster fell. Walls collapsed in other places. Children were thrown off their feet. My sensation in the open garden was that of giddiness, sickness and insecure foothold as on board ship, with a vibratory motion from the ground as well as a heaving or wave up and

down feeling. After 3 minutes of this, gradual subsidence occurred for ½ to 1 minute, and then calm. (A very slight tremor occurred again at about 3.35 P.M., duration about 10 secs. or less.) One expected the earth to give way, but no cracks are visible. The lines of the building resembled a jerky shaking outline. The house appeared to sway and rattle itself to pieces the whole time. (I liken it to a rough-haired dog shaking itself.) People say they remember nothing like it. Several brick buildings a mile and more away are damaged also.

'The rumbling appeared to come from south-west but may have been house noises or the galvanised iron roof and only apparent the first half minute I was in the house. I watched proceedings a safe distance out of doors. One felt giddy 15 minutes afterwards and there may have been a gentle wave motion of the earth after the 3 minute tremor.'

British Earthquakes.—There was no considerable earthquake in the British Isles during the year, but small disturbances, some of which may have been due to the collapse of old workings in mines, were reported by the newspapers as occurring on the following dates :

1933, October 28.	Nottingham.
1934, February 10.	Roslin, near Edinburgh.
1934, March 17.	Coasts of the Bristol Channel.
1934, April 23.	Elvington, near Dover.
1934, June 8.	Dufftown, Banffshire.
1934, August 16.	Dingwall and Cromarty.

Earthquake Prediction.

It has always been the desire of seismologists to be able to give warning of earthquakes. A letter from the Director of the Observatory at Manila, communicated by Mr. F. Hope-Jones, suggests a new line of research. The Observatory has been equipped with a synchronome 'Shortt' Free Pendulum, of the same construction as the Standard Siderial Pendulum at Greenwich. This type of pendulum has a variation of not more than about three seconds per annum. The Director's letter contains the following passage :

'Another interesting feature which I have noticed in your Synchronome (and also to a slight extent in the two Rieflers which I have) is the sensibility to a tilt in the land. On more than ten occasions some three or four days before a local earthquake the rate of the clock has changed very abruptly, varying as much as a tenth of a second within twenty-four hours, and then suddenly assuming a very slight rate which it keeps until the 'quake comes. After the 'quake the clock generally resumes its old rate, or one very near to it. There may be other explanations for this strange performance, but it may also prove to be a helpful hint in the apparently impossible solution of a method of predicting earthquakes of tectonic origin.'

Periodicity of Earthquakes.—The question whether earthquakes are more likely when the moon is in one position or another is frequently asked. An answer is to be found in a paper by Dr. C. Davison in the *Philosophical Magazine* for April 1934, 'The Lunar Periodicity of Earthquakes.' The earthquakes included in a number of catalogues have been investigated. The frequency of earthquakes tends in some cases to a maximum at the times of new and full moon but in other cases to a minimum. In the former category are such earthquakes in Japan as have their foci under the land, but Japanese earthquakes with foci under the sea are least frequent at new and full moon, as are the volcanic earthquakes of Honolulu. In the catalogues including earthquakes in all localities the minimum frequency is

at new and full moon. This may be because the majority of world-shaking earthquakes have epicentres under the oceans. The figures involved in these comparisons are such as to imply that the chance of an earthquake in a favourable part of the month is of the order 25 per cent. greater than the chance in an unfavourable part. Since the publication of his paper Dr. Davison has made the remarkable discovery that the focal depth of earthquakes in Japan is subject to a fortnightly period, the maximum depth occurring at the times of new and full moon.

Accounts.—The General Account of the Committee has been closed, the balance having been transferred to the University Observatory, Oxford. The grant of £100 from the Caird Fund was allotted to the Observatory.

The income of the Gray-Milne Fund has not recovered, the dividends due from the Canadian Pacific Railway having failed again. The principal call on the fund was on account of the new seismograph for Cape Town.

Gray-Milne Trust Account.

	£	s.	d.		£	s.	d.
Brought forward . .	374	17	9	Miss Bellamy (Honorarium) . . .	30	0	0
Trust Income . .	46	14	10	Milne Library . .	3	4	6
Bank Interest . .	1	17	0	Fire Insurance .	0	15	0
				Printing 'Constants'	7	0	0
				Seismograph . .	80	0	0
				Legal Expenses .	7	0	0
				Secretarial Expenses .	0	11	0
				Carried forward .	294	19	1
	£423	9	7		£423	9	7

Reappointment.—The Committee asks for reappointment, for the confirmation of the grant of £100 from the Caird Fund, and for a special grant of £50 for the maintenance of the International Seismological Summary.

MATHEMATICAL TABLES.

Report of Committee on Calculation of Mathematical Tables (Prof. E. H. Neville, *Chairman*; Prof. A. Lodge, *Vice-Chairman*; Dr. L. J. Comrie, *Secretary*; Dr. J. R. Airey, Prof. R. A. Fisher, Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. F. Robbins, Mr. D. H. Sadler, Dr. A. J. Thompson, Dr. J. F. Tocher and Dr. J. Wishart).

General activity.—Seven meetings of the Committee have been held in London.

Dr. E. S. Pearson, who found that he was unable, owing to pressure of other duties, to participate in the Committee's activities, resigned in November.

The grant of £100 has been expended as follows :—

	£	s.	d.
Calculations connected with the Bessel functions Y_0, Y_1, I_0, I_1, K_0 and K_1	95	0	0
Secretarial and miscellaneous expenses	5	0	0

Cunningham Bequest.—(*a*) The first volume printed under this Bequest, namely the Committee's Volume III, containing Prof. L. E. Dickson's *Minimum Decompositions into Fifth Powers*, was published in September 1933.

(*b*) Volume IV, prepared by Dr. E. L. Ince and entitled *Cycles of Reduced Ideals in Quadratic Fields*, was published in August.

(*c*) Volume V, containing the prime factors of all numbers from 1 to 100,000, is now in the press, and should be available before the end of 1934.

Since the publication of the last Report, it was learned that Prof. J. Peters, of Berlin, had completed in 1930 the manuscript of a table similar in all respects to the table that the Committee had undertaken. Prof. Peters kindly offered to place his manuscript at the disposal of the Committee; this offer was gratefully accepted. The table has thus been computed in triplicate.

(*d*) The 6-register National machine was delivered in August 1933, and has proved to be the most powerful aid to table-making yet known.

(*e*) The Brunsviga-Dupla, purchased in 1930, has been exchanged for a Brunsviga 20, of capacity $12 \times 11 \times 20$.

Bessel functions.—The publication of these tables, in two volumes, is now assured. A grant of £50 was made by the Royal Society, and a sum of £100 was voted by the Council. Arrangements have been made with the Cambridge University Press for the subsidised publication of Volume VI, containing the four principal functions of order 0 and 1, namely

(1) $J_0(x)$ and $J_1(x)$ to 10 decimals for
$$x = 0{\cdot}000(0{\cdot}001)16{\cdot}000(0{\cdot}01)25{\cdot}00.$$

(2) $Y_0(x)$ and $Y_1(x)$ to 8 decimals for $x = 0{\cdot}00(0{\cdot}01)25{\cdot}00$.

(3) M_0, N_0, M_1 and N_1 to 8 decimals for
$$x = 25{\cdot}00(0{\cdot}1)50{\cdot}0(1)100(10)1000$$

for use with the equations

$$\begin{aligned} J_0(x) &= M_0 \sin x + N_0 \cos x \\ J_1(x) &= N_1 \sin x - M_1 \cos x \\ Y_0(x) &= N_0 \sin x - M_0 \cos x \\ Y_1(x) &= -M_1 \sin x - N_1 \cos x \end{aligned}$$

(4) $I_0(x)$ and $I_1(x)$ to 8 decimals for $x = 0{\cdot}000(0{\cdot}001)5{\cdot}000$.

(5) $K_0(x)$ and $K_1(x)$ to 8 decimals for $x = 0{\cdot}00(0{\cdot}01)5{\cdot}00$.

(6) $e^{-x}I_0(x)$, $e^{-x}I_1(x)$, $e^xK_0(x)$ and $e^xK_1(x)$ to 8 decimals for
$$x = 5{\cdot}00(0{\cdot}01)10{\cdot}00(0{\cdot}1)20{\cdot}0.$$

(7) Auxiliary functions for the interpolation of $Y_0(x)$, $Y_1(x)$, $K_0(x)$ and $K_1(x)$ when x is small, i.e. less than 0·50.

The copy for this volume, which will contain about 300 pages, is practically complete, and composition will be put in hand shortly.

The second volume, for which much calculation remains to be done, will contain functions of fractional order and of order higher than 1, zeros of various functions, the Airy integral, the Kelvin functions ber, bei, ker, kei, and other allied functions.

The issue of *Nature* for 1934 March 17 contained a historical account of the Committee's activity since 1888 in the calculation of Bessel functions, and of the financial difficulties that have impeded publication. The article, after referring to the possibility of the Committee's work merely resting in manuscript in a fire-proof safe, concludes 'It ought to be sufficient, by directing attention to this possibility, to ensure that funds will be provided to . . . make available the result of so many years of voluntary work on behalf of mathematical students and others.'

Airy integral.—The calculation of this integral has been begun. The tabular values will be included in the second volume of Bessel functions.

Confluent hypergeometric functions.—11-decimal values of the functions $M(\alpha, 2, 10)$ and $N(\alpha, 2, 10)$ for $\alpha = 0{\cdot}0(-0{\cdot}2)-11{\cdot}0$ have been computed by Dr. A. J. Thompson, and communicated to Dr. R. Stoneley. These functions are defined by

$$M(\alpha, \gamma, x) = 1 + \frac{\alpha}{\gamma} x + \frac{\alpha(\alpha+1)}{\gamma(\gamma+1)} \frac{x^2}{2!} + \frac{\alpha(\alpha+1)(\alpha+2)}{\gamma(\gamma+1)(\gamma+2)} \frac{x^3}{3!} + \dots$$

$$N(\alpha, \gamma, x) = \frac{\alpha}{\gamma} x \left(\frac{1}{\alpha} - \frac{1}{\gamma} - 1\right) + \frac{\alpha(\alpha+1)}{\gamma(\gamma+1)} \frac{x^2}{2!} \left(\frac{1}{\alpha} + \frac{1}{\alpha+1} - \frac{1}{\gamma} - \frac{1}{\gamma+1} - 1 - \frac{1}{2}\right) + \dots$$

Sale of Volumes I–V.—Arrangements have been made with the Cambridge University Press to sell, on commission, the Committee's Volumes I–V.

Reappointment.—The Committee desires reappointment, with a grant for general purposes of £100.

INLAND WATER SURVEY.

Second Report of Committee appointed to inquire into the position of Inland Water Survey in the British Isles and the possible organisation and control of such a survey by central authority (Vice-Adml. Sir H. P. Douglas, K.C.B., C.M.G., *Chairman* ; Lt.-Col. E. Gold, D.S.O., F.R.S., *Vice-Chairman* ; Capt. W. N. McClean, *Secretary* ; Mr. E. G. Bilham, Dr. Brysson Cunningham, Prof. C. B. Fawcett, Dr. A. Ferguson, Dr. Ezer Griffiths, F.R.S., Mr. W. T. Halcrow, Mr. T. Shirley Hawkins, O.B.E., Mr. W. J. M. Menzies, Dr. A. Parker, Mr. D. Ronald, Capt. J. C. A. Roseveare, Dr. Bernard Smith, F.R.S., Mr. C. Clemesha Smith, Mr. F. O. Stanford, O.B.E., Brig. H. St. J. L. Winterbotham, C.M.G., D.S.O., Capt. J. G. Withycombe, Dr. S. W. Wooldridge).

The Committee records with deep regret the death of Capt. J. G. Withycombe, whose services on the Committee were of great value.

I. This Committee was appointed after the meeting of the British Association held at York in September 1932, on the recommendations of Section A (Mathematical and Physical Sciences), Section E (Geography), and Section G (Engineering), and was re-appointed in October 1933, with the same terms of reference.

On page 9 of the Committee's first report, presented in September 1933, its conclusions and recommendations are set out as follows :

'(i) That, with regard to the first part of the Committee's reference, the position of Inland Water Survey in the British Isles is far from satisfactory, and that a systematic survey of the water resources of Great Britain is urgently required ; and,

'(ii) That, with regard to the second part of the Committee's reference, the survey, to be of maximum utility, should be conducted by a central organisation, preferably under a Government department, independent of any interest in the administration, control or use of water.

'The Committee have given further consideration to steps by which the work of the survey could be most expeditiously begun. They have formed

the opinion that it would not be feasible, in the first instance, under present conditions, to move for the immediate establishment of an organisation to be financed by public funds, but rather that a beginning should be made in a comparatively small way, financed by subscriptions from individuals and bodies interested, with the prospect of being ultimately incorporated in a Government department.

'With this in view the Committee have approached the Council of the Institution of Civil Engineers and have been gratified to learn that the Council were prepared, if they are so requested by the British Association, to appoint a committee to investigate the feasibility of carrying out the objects outlined in this Report on a self-supporting basis.'

II. In pursuance of these recommendations the British Association communicated with the Institution of Civil Engineers, inviting them to carry the inquiry further. In response to this invitation the Institution appointed a committee 'to investigate the feasibility of carrying out on a self-supporting basis the objects outlined in the Report on Inland Water Survey.'

III. On June 8, 1934, this Committee was invited by the Committee of the Institution to co-operate in the formation of a small joint sub-Committee, consisting of three members from this Committee and three members from the Institution of Civil Engineers Committee, with a view to advancing the inquiry. It was considered that this action would be of advantage and the invitation was accordingly accepted.

IV. During the past year the Committee has reviewed the conclusions and recommendations contained in its first Report in the light of the improved financial position of the country and of the greater general interest in the subject as the result of the difficulties experienced during the exceptionally dry weather conditions. It was felt that the time was now opportune for the collection and correlation of data on inland water resources to be undertaken by some appropriate Government department, preferably one independent of any interest in the administrative control or use of water. The Committee therefore took steps to bring the matter to the notice of the Government through the agency of the joint sub-Committee mentioned in para. III. above.

V. In June 1934 a letter and memorandum, signed by the Presidents of the British Association and Institution of Civil Engineers, were submitted to the Prime Minister, and on July 17 a deputation was received by the Minister of Health. A statement on the result of the deputation to the Government (together with a copy of the letter and memorandum) is included in the appended report of the joint sub-Committee to the two main Committees. It will be noted that the Minister of Health stated that the suggestions put forward by the deputation would receive the most careful consideration of the Government.

VI. The Committee has noted with satisfaction that the Committee of Scottish Health Services has, in its Interim Report, 1934,[1] on Water Supplies, recommended that :

'(1) A technical survey of the water resources and supplies of Scotland should be undertaken at once.

'(2) A comprehensive inquiry should be held into the whole question of water supplies with the object of securing a more economical and more effective use of resources.'

It is also satisfactory to note that during the past year progress has been made by a number of undertakings in the establishment of further and improved gauging stations.

[1] H.M. Stationery Office. 49/9999. 1934. Price 1*d*.

VII. The Committee recommends that, in order to continue its work with a view to achieving the objects outlined in the report of 1933, it be re-appointed for another year with a grant of £100.

The Report of the joint sub-Committee is appended (A).

A.

Inland Water Survey.

Joint Sub-Committee of British Association and Institution of Civil Engineers Committees.

July 25, 1934.

Joint Committee's Report to Main Committees.

Resulting from the meetings of the Institution of Civil Engineers Committee on June 8 and of the Research Committee of the British Association on June 11, a joint sub-Committee was formed to discuss 'which Government department or departments should be approached in the matter, and the best method of approach.'

Mr. W. J. E. Binnie, Mr. T. E. Hawksley and Capt. W. N. McClean were appointed by the former Committee and Vice-Adml. Sir Percy Douglas, Dr. Brysson Cunningham and Mr. W. T. Halcrow by the latter Committee.

The Joint Committee held its first meeting on June 13; all members were present and Vice-Adml. Sir Percy Douglas was unanimously elected Chairman.

It was agreed that the Department of Scientific and Industrial Research was the right department to approach, and the Committee recommended that a deputation wait on the Prime Minister with a Memorandum presenting the case for the organisation of Inland Water Survey under the auspices of the above-named department.

The second meeting of the Joint Committee was held on Monday, June 18, and all members were present.

The draft Memorandum prepared by Dr. Brysson Cunningham, at the request of the Committee, was considered, amended, and approved.

The Memorandum was then submitted to Sir James Jeans, President of the British Association, and to Sir Henry Maybury, President of the Institution of Civil Engineers; the Committee requesting their consideration as to whether the Prime Minister should be invited to receive a deputation forthwith.

The two Presidents agreed to present the Memorandum, a copy of which is attached together with the letter accompanying it. (See B, below.)

The Deputation met Sir Hilton Young, Minister of Health, on July 17, and the official report which was given in *The Times* of July 18 reads as follows:

'Water Resources

'Suggested National Survey.

'Sir Hilton Young, the Minister of Health, who was accompanied by representatives of the various Departments concerned, received a deputation yesterday from the British Association and the Institution of Civil Engineers.

'The deputation was introduced, in the unavoidable absence of Sir James Jeans, by Sir Henry Maybury, and there were present Sir Percy Douglas, Sir Richard Redmayne, Prof. P. G. H. Boswell, Capt. W. N. McClean, Dr. Jeffcott, and Dr. O. J. R. Howarth.

'The purpose of the deputation was to invite the Government to give favourable consideration to the institution of a complete and systematic survey of the water resources of the country, a subject on which a Committee of the British Association has recently published a report.

'The deputation suggested that the existing records both of surface water, including river run-off, and of underground supplies were very incomplete. They urged that systematic records comparable with those of rainfall were much to be desired, and that a national survey was necessary in order to obtain statistics of this nature.

'Sir Hilton Young, in reply, thanked the British Association and the Institution of Civil Engineers for the consideration which had been given to the matter and for the suggestions which had been made, and said that these suggestions would receive the most careful consideration of the Government. Sources of information were available through the Ministry of Health, the Geological Survey, and the Catchment Boards. It was for consideration whether the progress which was to be desired in the collection of statistics could not best be achieved by improving the existing means of gauging the flow of rivers and by improvements in the method of collecting and presenting returns.'

The joint sub-Committee await with interest the result of the Government's careful consideration of the matter.

B.

The Rt. Hon. J. Ramsay Macdonald, P.C., M.P., F.R.S.
Prime Minister,
10 *Downing Street, S.W.* 1. June 23, 1934.

Sir,—We beg leave to submit herewith a memorandum on the subject of an Inland Water Survey, which is the outcome of the work of Committees of the British Association and the Institution of Civil Engineers during the past two years. In the belief that this is a matter of national urgency, we venture to ask whether you would be so good as to receive us and some of our colleagues as a deputation to discuss the matter further.

We are, Sir,
Your Obedient Servants,
J. H. Jeans,
President of the British Association for the Advancement of Science.
Henry Maybury,
President of the Institution of Civil Engineers.

To the Right Hon. J. Ramsay Macdonald, P.C., M.P., F.R.S.,
Prime Minister.

Memorandum on Inland Water Survey.

Sir,—The situation created by the present unprecedented shortage of water in the country and the emergency measures which have had to be taken in consequence impels us to lay before you a cognate matter of no less vital importance which has been a source of concern for many years past to responsible officials and those engaged in connection with water undertak-

ings and all others interested in the flow of rivers and streams. This is the pressing need for a complete and systematic investigation of the water resources of the country carried out under auspices of an unquestionably impartial and disinterested character.

The call for a national Inland Water Survey dates back for many years. It can be traced as far as the time of the eminent engineer Telford, who, in 1834, prepared a report on the Means of Supplying the Metropolis with Pure Water. During the century which has elapsed since then, it has been repeated on numerous occasions in the proceedings of scientific and technical societies and in reports presented to the Government by various commissions of inquiry. Of late, it has become so widespread and insistent that in September 1932, at the instance of a number of engineers and scientists, the British Association appointed a representative committee of professional men and departmental officials to inquire into the whole matter and to consider the possible organisation and control of such a survey by central authority.

This committee made a careful investigation extending over many months into all the available sources of information, and in the end drew up a Report which was presented to the British Association in September last. The Report, a copy of which is appended, sets out the urgent representations which have been made from time to time during the past fifty years for a thorough examination and an efficient control of the national water resources, in accordance with the practice of other leading countries, which it is shown have instituted and maintain organisations for investigating, conserving and allocating their own supplies. By way of exemplification, it is only necessary to quote the following brief but emphatic statement from the Final Report (1921), of the Water Power Resources Committee of the Board of Trade :

'We find that the difficulty in fairly allocating the natural sources of water is becoming greater year by year in England and Wales, and the evidence we have heard proves beyond doubt the urgent necessity in the national interests of some measure of control of all water, both underground and surface, in order that the available supplies may be impartially reviewed and allocated, and may be made to suffice for all purposes in the future. In consequence of the increase of population, the improvement in conditions of life and the growing requirements of industry, the demand for water is steadily increasing, and the problem of meeting future needs is giving rise to anxiety in many parts of England and Wales.'

To this it may be added that the recently issued (1934) Report of the Committee on Scottish Health Services appointed by the Secretary of State for Scotland affirms, with equal conviction, cause for similar anxiety in Scotland, and urges that 'a technical survey of the water resources and supplies of Scotland should be undertaken at once.'

Justifiably impressed by the overwhelming weight of evidence, the British Association Committee came unanimously to the following conclusions :

(1) That a systematic survey of the water resources of Great Britain is urgently required, and
(2) That the Survey, in order to be of maximum utility, should be conducted by a central organisation, preferably under a Government department, independent of any interest in the administration, control or use of water.

After consideration of various alternatives, it was decided to recommend that a beginning be made in a comparatively small way financed by subscriptions from individuals and bodies interested, with the prospect of being ultimately incorporated in a Government department.

Accordingly the British Association, having adopted the Committee's Report, invited the Council of the Institution of Civil Engineers to take the matter up, and they, in turn, appointed a Committee for the purpose of ascertaining whether it was feasible to carry out a scheme on a self-supporting basis. In view of the adverse replies received with regard to finance as a result of an appeal to the Catchment Boards and other authorities for technical and financial support, this has been found to be impracticable.

The experience of the present drought has brought home to the public mind the vital importance of conserving the national water resources. Both the British Association Committee and the Committee of the Institution of Civil Engineers now feel not only that they have every justification for so doing, but that the time is eminently opportune and propitious for an appeal to the Government to take action and to set up an organisation to undertake a comprehensive inland water survey.

We suggest that effect might be given to this recommendation through the agency of the Department of Scientific and Industrial Research by the appointment of a special board, with a headquarters staff, to deal with the collection, collation and technical direction of water measurements and gaugings throughout the country. The records of water undertakings, river conservancies and catchment boards, as well as readings due to private enterprise, could be drawn upon for the supply of data, and further observations and measurements made as may be found necessary.

The Department of Scientific and Industrial Research, comprising as it does such related branches of work as the Geological Survey and Water Pollution Research, seems to us particularly adapted for scientific investigation of this kind, and we are greatly influenced by the consideration that it is entirely independent of interest in the use and control of water, a qualification which we hold to be of the highest importance.

It is not necessary at this stage to discuss in detail the system of organisation for the proposed department, but in outline it might consist of an unpaid board with a salaried staff. Voluntary assistance by competent persons might be available in various parts of the country, as in the case of the British Rainfall Organisation. The department would undertake the publication of records at a suitable charge which should materially assist towards the cost of the survey.

Before the most effective use can be made of the country's water resources it is imperative that the fullest information be available respecting the quantity and locality of supplies, and for this purpose a thorough and impartial survey is essential.

We respectfully urge, therefore, that His Majesty's Government will give our recommendation their immediate and favourable consideration, in view of the important national interests which are involved.

We are, Sir,
Your Obedient Servants,
J. H. Jeans,
President of the British Association for the Advancement of Science.
Henry Maybury,
President of the Institution of Civil Engineers.

At the Aberdeen Meeting, on the recommendation of Sections A (Mathematical and Physical Sciences), C (Geology), E (Geography), and

G (Engineering), the following resolution was forwarded by the General Committee to the Council for consideration and, if desirable, for action :

> That the British Association awaits with great interest the result of the careful consideration which His Majesty's Government has promised to give to the question of an Inland Water Survey, and trusts that the Government will be favourable to the establishment of an organised survey of the water resources of the country on a scientific basis.

ZOOLOGICAL RECORD.

Report of Committee appointed to co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the 'Zoological Record' (Sir Sidney Harmer, K.B.E., F.R.S., *Chairman* ; Dr. W. T. Calman, F.R.S., *Secretary* ; Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S.).

The grant of £50 was paid over to the Zoological Society on June 2, 1934, as a contribution towards the cost of preparing and publishing Volume LXIX of the *Zoological Record* for 1932. The statement of the 'Record Fund' given in the report of the Council of the Zoological Society for 1933 shows that the balance in hand had again increased slightly, from £2,286 15*s.* 4*d.* to £2,317 18*s.* 2*d.* The loss on Volume LXIX is given as £1,055 16*s.* 6*d.*, against which has to be set £246 7*s.* 11*d.* received from sales of back volumes, leaving a net deficit of £809 8*s.* 7*d.* This is met by contributions of £500 from the Zoological Society, £200 from the Trustees of the British Museum, and smaller sums from other contributing societies. It is clear that the *Zoological Record* could not be carried on without such help, and it is, therefore, most important that the support of the British Association should be continued. The Committee accordingly asks for reappointment, with the renewal of the grant of £50.

HUMAN GEOGRAPHY OF TROPICAL AFRICA.

Report of Committee appointed to inquire into the present state of knowledge of the Human Geography of Tropical Africa and to make recommendations for furtherance and development (Prof. P. M. Roxby, *Chairman*; Prof. A. G. Ogilvie, O.B.E., *Secretary*; Mr. S. J. K. Baker, Prof. C. B. Fawcett, Prof. H. J. Fleure, Dr. A. Geddes, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Col. M. N. MacLeod, D.S.O., M.C., Prof. J. L. Myres, F.B.A., Dr. R. A. Pelham, Mr. R. U. Sayce, Rev. E. W. Smith).

In the Report for 1932–33, which summarised the past activities of the Committee, it was pointed out that the Government of Northern Rhodesia had responded to the request for answers to the questionnaire in respect of most of the Districts of the Protectorate. Two further reports have been received, making a total of thirty, while only two are now outstanding.

During the past year it has been decided that the Committee should undertake the compilation of a small volume based upon these reports and comprising an account of the Social Geography of Northern Rhodesia. Considerable progress has been made towards this end by the Secretary, and a forecast of part of the content of the work is indicated in the Presidential Address to Section E (Geography) for the present year. At the same time the Committee felt that the original reports themselves constitute valuable documents which should be preserved and be made available to facilitate other research work in the fields of geography and anthropology. At its request, a special grant of £5 was made by the Council to enable the Committee to copy the originals by the photostat process on a reduced scale. But unfortunately this grant has been found to cover only half of the cost of copying. The Committee is therefore including a like sum in its present application, to complete the work.

Contact has now been established with other bodies interested in its work and mentioned in its previous Report, and there is every prospect of close co-operation.

The visit of Mr. S. J. K. Baker to East Africa has already borne some fruit by his publication of a paper interpreting the population map of Uganda (in the *Uganda Journal*, 1934); while Mr. Baker has also prepared a general population map of East Africa based upon all available material. The Committee has decided to approach the various Governments with a view to obtaining more detailed material for the compilation of population density maps of all the British territories.

In the past year the paper by Messrs. E. A. Leakey and N. V. Rounce on the Kasulu District of Tanganyika has been published in *Geography* (1933).

The Committee has spent £3 6*s*. 2*d*. of its grant of £5, while a profit from sales of the pamphlet amounting to £1 5*s*. 3*d*. has been handed to the General Treasurer.

The Committee asks for reappointment with the addition of Mr. W. Fitzgerald, and applies for a grant of £25 for the following purposes: (*a*) to complete the photostat copying of the Northern Rhodesia reports; (*b*) to cover expenses to be incurred in preparation of the work on the Social Geography of Northern Rhodesia with a view to publication; (*c*) for the purchase and distribution of separate copies of articles communicated to societies for publication; and (*d*) for secretarial expenses during 1934–35.

EARTH PRESSURES.

Ninth Interim Report of Committee on Earth Pressures (Mr. F. E. WENTWORTH-SHIELDS, O.B.E., *Chairman*; Dr. J. S. OWENS, *Secretary*; Prof. G. COOK, Mr. T. E. N. FARGHER, Prof. A. R. FULTON, Prof. F. C. LEA, Prof. R. V. SOUTHWELL, F.R.S., Dr. R. E. STRADLING, Dr. W. N. THOMAS, Mr. E. G. WALKER, Mr. J. S. WILSON).

SINCE their last report, the Committee have learnt with deep regret that, owing to serious illness, Prof. Jenkin has been obliged to abandon the work in which he and they have been so keenly interested.

The Committee would like to place on record their very high appreciation of the great value and importance of Prof. Jenkin's contribution to the solution of earth pressure problems.

The Committee have received a report from Prof. Jenkin, in which he summarises his general conclusions at the stage when he was obliged to discontinue his researches. He also emphasises the practical importance of the subject, and the desirability of completing the investigation. The report is attached.

The Committee have also before them a report from the Research Station, written by Mr. D. B. Smith, B.A., which is an account of his collaboration with Prof. Jenkin on the experimental work on Kaolin, which has been carried out at the Research Station since 1932.

This work is not complete, but the Committee hope it will be published, either by the Association or elsewhere, because it contains very valuable information and also because it will give most useful guidance to future investigators.

Although, if Prof. Jenkin had been able to continue his work, he would doubtless have made some further experiments on these lines, he has expressed the view that this particular field of investigation will not yield much further result.

Nevertheless, Dr. Stradling is anxious that the Committee should continue to keep in touch with the work connected with earth pressures which is being carried out at Garston.

The Committee too are anxious to do so, because they realise that this work will assist the solution of those earth pressure problems which are its chief interest.

They therefore ask to be reappointed.

THE MECHANICS OF GRANULAR MATERIAL

BY

C. F. JENKIN, C.B.E., F.R.S.

Preface.

The writer has been working at the theory of the mechanics of granular material for many years; his researches have now been brought to an end by failing health. This paper summarises the general conclusions at which he has arrived, and may be of some use to those who follow; it does not pretend to be a scientific paper, for no proofs of the statements it contains are given.

Introduction.

So far as the writer is aware there has never been any thorough investigation into the mechanics of granular material. The importance of the subject may be indicated by giving a list of some of the subjects for which a theory of the mechanics of granular material is wanted.

1. Foundations (bearing pressures of soil).
2. Retaining walls, dock walls, etc. (horizontal earth pressures).
3. Earthworks (railway cuttings and embankments).
4. Landslides and their prevention.

   (Items 1–4 have been entered without qualification, since clay and other cohesive soils have now been shown to be granular materials (see p. 249).)
5. Cement, mortar and concrete (grading, ramming and measuring workability).
6. Roads (foundations, ballast, ramming and rolling both foundations and concrete and surface material).
7. Silos, bins and hoppers for storing grain, coal, road-metal, etc. Design of the buildings and design of the valves and chutes for controlling the outflow.

Dry Granular Material.

The two physical properties of granular material on which their remarkable mechanical properties mainly depend are their compactability and dilatancy.

Compactability denotes the most widely known property of granular material, namely, that its specific volume depends on the closeness of the packing of the grains. How to produce closest packing is unknown, and the primitive methods of ramming and shaking [1] are still used, though anyone who has experimented with them knows how uncertain their results are. Specific volume and closeness of packing are often measured by the 'percentage of voids,' the term 'void' being used to denote the spaces not occupied by the solid grains; the spaces are still called 'voids' when partly or completely filled with water.

Dilatancy denotes the converse property of all granular material (except when very loosely packed) of expanding in volume when its shape is changed, i.e. when it undergoes shear strain.

Dilatancy has been discussed by the writer in his paper on 'The Pressure Exerted by Granular Material,' *Proceedings Royal Society*, vol. 131, 1931, p. 53. Dilatancy causes granular materials to move in jerks instead of uniformly; a familiar example is the alternate building up and collapse of the cone of sand in the bottom of an hour-glass. The cyclic movement of sand slipping down against a retaining wall is described in the writer's paper on 'The Pressure on Retaining Walls,' *Proceedings Institution of Civil Engineers*, vol. 234, 1931–32, Part 2, p. 103. This cyclic motion provided the clue to the theory of pressures on retaining walls given in that paper, which the writer believes to be the first paper to take account of the actual behaviour of granular material.

The importance of dilatancy has been further emphasised by the writer's recent discovery that *clay* exhibits this phenomenon. He has been working for the past eighteen months exclusively on the mechanics of plastic China clay and has tested it in compression, tension, simple shear, shear plus end compression, and in compression plus hydraulic pressure, besides

[1] *Cf.* 'Good measure, pressed down, and shaken together' (St. Luke vi. 38).

making many special tests. All these tests indicate that China clay behaves as a very fine wet granular material (for definition, see p. 250); that is to say, exhibits compactability and dilatancy and cohesion due to the water content. As *dry*, *wet* and *moist* sand (as defined later) all exhibit the same phenomena, it is probable that *all soils* exhibit the fundamental properties of granular materials.

Cohesive Granular Material.

The cohesive materials here discussed are only the granular materials rendered cohesive by the presence of water or other liquid; all soils, including clay, except when baked dry, come under this definition, also freshly mixed cement, mortar, and probably concrete and plaster, before they set. Tar-macadam and such road materials are included.

Just as the old theories of the mechanics of dry granular material, such as Rankine's, are necessarily imperfect because they neglect the effects of compactability and dilatation, so the old theories of cohesive granular material, arrived at by endowing such dry granular material with a shear strength, are also imperfect and may lead to very erroneous results. The writer has come to the conclusion that there are certainly two (possibly more) different types of cohesive granular material of common occurrence which possess quite different properties; they may be called:

1. Moist granular material, and
2. Wet granular material.

1. *Moist Granular Materials.*—The common example of this type is damp (not saturated) sand. It has been much studied in agricultural research. Each grain is wet and where they touch a little disc of water forms, bounded by an annular meniscus. The surface tension on this meniscus exerts a small force, drawing the grains together. The magnitude of the forces and their dependence on the size of the grain and the amount of water is discussed in Fisher's papers, ' On the Capillary Forces in an Ideal Soil ' (*Journal Agricultural Science*, 1926, pp. 492–503; 1928, pp. 406–410). The ' voids '—i.e. spaces between the grains—are filled partly by air and partly by water. If the quantity of water is sufficient to fill the voids, thus excluding air, the meniscuses disappear and the conditions entirely change. If the water dries up the meniscuses disappear and the conditions change to those of ordinary dry granular material, except when the material sets solid, which is notably the case when there is very fine granular material present—i.e. colloidal material—which ' glues ' the grains together.

Compactability.—Moist granular material is compactable, like dry granular material. During compaction the percentage of voids decreases and more points of contact arise, so that the cohesive forces change. As the packing gets still closer a state may be reached when the voids are entirely filled with water, and cohesion will disappear. The material then ceases to be moist granular material.

Dilatancy.—Moist granular material exhibits dilatancy just as dry granular material does. During dilatation the number of meniscuses is reduced and the cohesive forces change. Saturated granular material may be converted into moist material by dilatation, the free water being sucked into the voids, followed by air. This phenomenon was described by Osborne Reynolds in his original paper.[2]

An admirable material for experiments on this type of granular material may be made by stirring a few drops of olive oil into a beaker-full of the minute spherical beads known as ' glistening dew ' (vide *Proceedings Royal*

[2] *Vide* vol. 2 of Osborne Reynolds' *Scientific Papers*, Cambridge University Press.

Society, loc. cit.). The oil quickly coats every bead and provides the minute discs and meniscuses at every point of contact. Oil is preferable to water, which dries up too quickly. By varying the size of the beads and the nature of the liquid the properties can be varied. The writer has experimented with this material, but has made very few mechanical tests on it. The mechanical properties of moist granular material await investigation.

2. *Wet Granular Material*.—Only extremely fine granular materials form stable masses when saturated with water, and it is only with these that we are here concerned. Saturated gravel or sand (except the finest) slumps down and the water drains off; we are not concerned with such substances. Coarse granular material *under water* behaves like dry material (see the writer's Institution of Civil Engineers paper, *loc. cit.*).

Very fine granular material, such as China clay powder, when stirred up with water only settles very slowly. If the sediment is removed from the water, more water drains off, but the mass remains saturated throughout. If the sediment is put into a filter press more water may be extruded, and the material remaining is a more or less plastic mass held together by the negative water pressure or 'suction' of the water in the 'voids. It possesses resistance to deformation (shear strength), which is due to the friction between the grains held together by the suction.[3] The suction or negative water pressure would draw in air but for the layer of water on the surface of the mass; the suction draws this surface layer of water into each space between the surface grains, forming innumerable minute meniscuses which support the suction.

Compactability.—Wet granular material, as defined above, is almost incompressible, since it is made up of solids and water; but if the water is allowed to escape (as, for instance, in a filter press), it is just as compactable as dry granular material, and any type of 'working,' as before, facilitates the packing of the grains. A slight alternating torsion produced by rotating the piston of the press backwards and forwards through a small angle is effective, but how to produce the closest packing is not known. The unwanted extrusion of water from clay due to unexpected compaction is liable to interfere with all tests or methods of preparing test-pieces which are carried out in closed vessels. The sudden appearance of drops of water oozing out through the joints of the apparatus is a most familiar sight, and sets a limit to the range of many tests. Extrusion of water from a free surface never takes place.

The permeability of ultra fine-grained material is very small, so that the water can only escape slowly, and time is required for compaction.

Dilatancy occurs in wet granular material, as defined above, just as in dry granular material, but its results are different because the volume of wet material cannot expand (the minute elastic expansion and the minute expansion permitted by the increased depth of the surface meniscuses may be neglected at present).

When wet granular material is sheared the incipient dilatation causes a rapid rise in the suction. The rise in the suction involves an increasing compressive stress which has two effects: firstly, it increases the friction between the grains and consequently the resistance to shear; secondly, it begins to compact the mass. The combined result of the dilatation and this compaction is that the volume remains almost constant while the suction and shear strength rise. This action continues till one or other of two[4]

[3] Molecular forces probably also have an appreciable effect.

[4] A third condition appears to limit the strain in tensile tests on clay, but too few tests have been made to determine what happens with certainty.

conditions supervenes : (i) either the suction reaches the maximum value which the surface meniscuses can bear, in which case they break and air enters the mass ; as the shear strength can get no greater the mass fractures, the air enters the plane of fracture and the break looks like a break in stone ; or (ii) the dilatation reaches its full value, the suction ceases to rise and the strength also ceases to increase ; the mass then yields freely in shear ; it is not broken in two. Both types of failure have been produced experimentally in compression test-pieces ; the first is typical of non-plastic materials and the second of plastic materials, such as clay.

At first sight the conception of simultaneous dilatation and compaction may appear paradoxical and unnecessary, but further consideration leads to the conclusion that it is the obvious way of accounting for the observed facts that the suction rises and the strength increases while the volumes cannot change. An interesting comparison may be made with the experiment quoted on p. 54 of the author's Royal Society paper (*loc. cit.*), in which an attempt was made to shear dry sand in a closed vessel ; dilatation prevented any motion till the sand crushed under a very large stress (the sand in that experiment had been closely packed so that further compaction—except by crushing—was impossible).

This brief outline of what happens when wet granular material is sheared leaves out of account many factors which probably play important parts. The shape of the grains, and possibly their mechanical deformation, is believed to be important in determining the plasticity of clay. Again, the grains in clay are so small that forces which may be called molecular or electric must play an important part. What the relative importance of the different factors may be has not yet been determined ; all that the writer claims is that China clay has been proved to exhibit compactability and dilatancy and must be classed as a wet granular material, whatever other properties it may have. The fact that China clay turned out to exhibit dilatancy, contrary to expectation, was the reason that the whole series of researches just completed at the Building Research Station turned out to be inconclusive.

Conclusion.

Now that the finest ground sand and the much finer China clay have been proved to exhibit compactability and dilatancy the writer has no longer any doubt that cements, plasters, mortars and concretes will all be found to exhibit the characteristic properties of granular materials, and that when mixed with water they will be found to belong to the classes of moist or wet granular materials as defined above.

It would be difficult to name any fundamental research that has such a close connection with buildings and roads as the investigation of the mechanics of granular material. The writer hopes that the work may be successfully completed at the Building Research Station.

STRESSES IN OVERSTRAINED MATERIALS.

Interim Report of Committee on Stresses in Overstrained Materials (Sir Henry Fowler, K.B.E., *Chairman* ; Dr. J. G. Docherty, *Secretary* ; Prof. G. Cook, Prof. B. P. Haigh, Mr. J. S. Wilson).

The Committee finds that the programme of investigation outlined in previous reports has proceeded more slowly than was anticipated, and no extended report is possible this year. Prof. Cook has published a paper on 'The Stresses in Thick-walled Cylinders of Mild Steel overstrained by Internal Pressure' in the *Proceedings* of the Institution of Mechanical Engineers, and Prof. Haigh is presenting to Section G a paper recommending the more general specification and use in design of the Lower Yield Point of mild steel, which bears directly on the work of the Committee. This is not put forward as a report, but will be referred to when, as is hoped, the Committee presents a full report next year.

The Committee asks to be reappointed for another year.

THE REDUCTION OF NOISE.

Report of Committee, with terms of reference stated below (Sir Henry Fowler, K.B.E., *Chairman* ; Wing-Commander T. R. Cave-Browne-Cave, C.B.E., *Secretary* ; Mr. R. S. Capon, Dr. A. H. Davis, Prof. G. W. O. Howe, Mr. E. S. Shrapnell-Smith, C.B.E.).

The Committee was set up to review the knowledge at present available for the reduction of noise and the nuisances to the abatement of which this knowledge could best be applied.

Sir Henry Fowler, K.B.E., was appointed Chairman, Wing-Commander Cave-Browne-Cave, C.B.E., Hon. Secretary, Mr. Capon and Prof. Howe were appointed members, and to these Dr. Davis and Mr. Shrapnell-Smith were added later.

A grant of £10 was made to cover correspondence, and at the beginning of May 1934, the Association, finding that there was a balance of £24 outstanding in one of their other accounts, allotted it to the work which was being done for the Committee on the reduction of exhaust noise.

The Chairman wrote to *The Times* on September 30, 1933, inviting reasoned opinions from members of the public as to the noises which caused them most discomfort and inconvenience.

A very large number of replies to that letter were received and analysed. They led definitely to the conclusion that the sources which caused most annoyance and inconvenience were inadequately silenced motor bicycles and cars, then motor horns, other road transport noises, and finally aircraft.

No other noise caused half the complaint levelled against the last of this first group (aircraft).

The Committee realised that the Air Ministry was doing everything possible to reduce the noise of aircraft as heard by passengers and also by persons on the ground.

The Committee, therefore, decided first to devote their attention to the general problem of exhaust noise of motor bicycles and sports cars. They also decided to invite Messrs. Lucas, a firm who make a great variety of

electric motor horns and other devices for giving the audible warning of approach specified in the Act, to prepare a paper examining the characteristics which render such a signal effective as well as those which cause it to be offensive.

This paper will be read by Mr. E. O. Turner, and a demonstration of various sound signals will be given.

Wing-Commander Cave suggested that in order to produce a general decrease in exhaust noise it was necessary not only to determine the principles on which better silencers should be based, but to outline an organisation whereby these principles could be given general practical effect. He proposed that the Committee should work towards the objective of enabling an authority to be set up to which manufacturers could submit new types of motor vehicle to be tested for a certificate of approved silence.

For this purpose it would be necessary to determine a satisfactory instrument for measuring the noise produced by the vehicle and to specify the conditions under which tests should be made.

It would also be necessary to indicate to this authority what should be accepted as a reasonable standard to which vehicles must conform. For this latter purpose he proposed to undertake some preliminary tests upon the silencers of motor bicycle engines.

He was able to obtain the advice of the Motor Cycle Manufacturers and Traders Union as to the requirements which a silencer must meet. He then made some preliminary experiments to determine which general principles of noise reduction were the most effective. The results of these preliminary tests were encouraging, but the subsequent experimental work, carried out at the University College, Southampton, was only rendered possible by a donation of £50 made by Lord Wakefield to him for that purpose.

A number of designers visited Southampton, and considered the preliminary results so far satisfactory that they selected and sent to Southampton a 2-stroke and 4-stroke bicycle, each of normal type, as sold to the public.

Wing-Commander Cave's work and the conclusions which he has reached will be described in his own paper and demonstrated in trials on the road. They indicate that it is now quite possible to effect a great reduction of exhaust noise by the use of a silencer which results in a small increase of horse-power rather than a decrease when compared with that attained with the silencers as now commercially sold.

The Committee wishes to express its great appreciation of the assistance rendered by the Motor Cycle Manufacturers and Traders Union in discussing the problem and then supplying Wing-Commander Cave-Browne-Cave with the two bicycles and every incidental detail he required.

Dr. Davis, of the National Physical Laboratory, agreed to undertake a critical review of various instruments and methods available for measuring noise, with particular reference to the question of testing noises of a given type, e.g. exhaust noises. His conclusions will be given in his paper and suggest that, if agreement can be reached as to the conditions under which a test could be made, it is within the scope of suitable noise meters, which do not depend upon personal judgment, to determine satisfactorily whether the noise of a unit submitted for test does or does not exceed that of a standard noise of the same kind agreed to be the maximum acceptable under a regulation.

The whole of the money allotted to the Committee has been spent, and if the full cost taken by University College, Southampton, were included, there would be considerable over-expenditure, even with Lord Wakefield's generous donation.

The Committee prefers to wait until it has heard the discussion on these three papers before it makes any definite recommendation as to further work which should be undertaken.

DERBYSHIRE CAVES.

Twelfth Interim Report of Committee appointed to co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district (Mr. M. C. Burkitt, *Chairman*; Dr. R. V. Favell, *Secretary*; Mr. A. Leslie Armstrong, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake).

No new excavation work has been undertaken by the Committee during the current year, but the excavation of the Pin Hole Cave, Creswell Crags, has been steadily advanced by Mr. Leslie Armstrong, F.S.A., and it is anticipated that this work will be completed during the coming autumn.

The following reports have been submitted.

Report on Excavations in the Pin Hole Cave, Creswell Crags.

By A. Leslie Armstrong, F.S.A.

Subsequently to the presentation of my last report, the section in the rear of the main chamber, then under examination, was completely excavated to the base level just prior to the Leicester Meeting of the Association, thereby enabling the complete stratification of the cave deposits, 17 ft. in thickness, to be exposed for examination by Section H during the visit to the cave on September 9, 1933. After inspecting the section the Chairman and members of the Committee present agreed that the excavation of a further portion of the rear passage was desirable before closing down the work, and that ultimately a typical section of the deposits, similar to that exposed on this occasion, should be permanently preserved. The examination of an additional 15 ft. was therefore commenced during October 1933, and, at the time of writing, one-third of this length has been excavated to the base level, a total depth of 18 ft.; a further one-third down to the 12-ft. level; and the remainder to the depth of 6 ft. Though the width of this portion of the cave nowhere exceeds 5 ft., and in places is only 2 ft., progress has been slow and the work somewhat laborious on account of the layer of hard crystalline stalagmite, 9 in. to 12 in. in thickness, which crowned the deposit, and the numerous slabs and masses of fallen limestone which were cemented into it. Jumbled rocks, of large size, have also been unusually numerous within the cave earth and, in places, completely blocked the passage. The stratification, however, has been well defined throughout, and the two layers of fallen slabs which throughout the cave have so consistently separated the Mousterian (1) and (2) and Mousterian (2) and (3) levels have been equally well marked in this portion also. Having regard to the fact that the presence of so many fallen blocks must have always rendered this part of the cave unsuitable for occupation, it was anticipated that artifacts would be few, but that the chance of discovering human remains was promising. Unfortunately, the latter has not been realised, but artifacts, in all levels, have been more numerous than was expected. A cavity in the upper surface of the stalagmite, filled with slightly brecciated black earth, yielded pins of mediæval type and a small Saxon brooch, in bronze, of cruciform pattern. A sherd of Iron Age

pottery occurred in a similar cavity. The upper cave-earth yielded several artifacts of flint, including a fine battered-back knife from the Font Robert level, tools of limestone, and pieces of worked bone and reindeer antler.

Fish scales and portions of a large egg, probably duck, occurred in the same level, also pot boilers of stone and fragments of charcoal around a possible, but not well-defined, hearth.

Tools of quartzite, crystalline stalagmite and limestone, similar to specimens previously found, have occurred in each of the three Mousterian levels. Two finds of special interest have been made in the 12-ft. layer, Mousterian (2) in age. The first of these is a bone tool 2 in. long, roughly triangular in form, with a base $\frac{1}{2}$ in. wide, cut into the form of two prongs, each 1 in. long. The second appears to be a bone "bull roarer." It is $3\frac{1}{2}$ in. long, $\frac{7}{8}$ in. wide, and of pointed oval form, perforated near one end and having an extreme thickness of about $\frac{1}{8}$ in.

In comparison with other portions of the cave, animal remains have been less numerous, and no additions have been made to the fauna already recorded. During the spring a number of flies were collected, infested with fungi. These I submitted to Mr. T. Petch, F.R.M.S., who has kindly supplied the accompanying report, from which it will be observed that the specimens include new species of fungi and others of special interest. A report by Dr. J. W. Jackson, on the remains of small mammals, etc., collected, is also attached.

I anticipate that the excavation will be completed early in the coming autumn, and I propose to leave an entire cross-section of the deposit exposed to view. This will form the most complete and representative stratified section of the Upper and Lower Palæolithic cave deposits of Britain, and it is earnestly hoped the Committee will take the necessary steps to preserve it intact as a British type section, adequately protected against unauthorised interference.

Future Work.—An unexpected opportunity has presented itself for the immediate excavation of the Boat House Cave, on the southern side of the gorge and at its eastern extremity, through the draining of the lake which has hitherto occupied the bed of the gorge and prevented any examination of this cave.

It will be necessary to undertake the work without undue delay. A trial section has yielded promising indications and proved that the deposits are entirely undisturbed.

I propose, subject to the sanction of the Duke of Portland, to commence this work immediately upon the completion of the Pin Hole excavations.

Report on Fungi occurring on Flies collected in the Pin Hole Cave.

By T. Petch, B.A., B.Sc.

Five species of fungi have been identified on the flies collected by Mr. Leslie Armstrong in Pin Hole Cave. These are :

(1) *Hirsutella*, new species, parasitic on *Blepharoptera*.
(2) *Stilbella Kervillei* (Quel.) Lingelsh., parasitic on the *Hirsutella*.
(3) *Spicaria* (*Isaria*) *farinosa* (Holms) Fr., parasitic on gnats.
(4) *Sporotrichum Isariæ* Petch, parasitic on *Spicaria* (*Isaria*) *farinosa*.
(5) *Beauveria Bassiana* (Bals.) Vuill., parasitic on a fly.

Hirsutella sp. nov.—This fungus first forms discontinuous brown patches of mycelium on the body of the insect, and subsequently, erect fuscous clavæ, up to 8 mm. long and 0·2 mm. diameter. In this condition the fungus is fertile and identifiable.

Very frequently, however, the *Hirsutella* develops into long hair-like

strands, 8 cm. or more long, frequently branched. In that state the strands are usually sterile. A similar phenomenon occurs in the case of the common tropical *Hirsutella* on *Hymenoptera*, *Hirsutella Saussurei*, in which small clavæ, a few millimetres long, are fertile, but the conspicuous long black clavæ, 5 cm. or more long, are sterile. Several of these abnormal sterile forms of the new British species have been collected by Mr. Armstrong, but they could not be identified until the smaller fertile form was found. There is also a specimen in the Herbarium of the British Museum (Natural History), a fly (*Blepharoptera serrata* Fabr.) bearing long sterile hair-like clavæ, collected ' in a stalactite cave,' Yealhampton, Devon, June 1906, which can now be assigned to the new British species of *Hirsutella*.

Only one normal unparasitised specimen of this *Hirsutella* occurs in Mr. Armstrong's collections.

Stilbella Kervillei (Quel.) Lingelsh.—This species was described by Quelet from specimens, apparently parasitic on flies (*Blepharoptera*), found in caves in France. It has since been found in caves elsewhere on the Continent. Mr. Armstrong's specimens, first found in the Creswell Caves in 1923 and recorded by Mr. F. A. Mason in *Journal of Botany*, August 1931, pp. 205–207, were the first to be found in Britain. More recently several examples have been collected by Mr. Armstrong in Pin Hole Cave.

Quelet described his species as having a simple white stalk and a yellow globose head, but with brown mycelium on the body of the insect, an unusual difference in colour. Mr. Armstrong's first specimens agreed with Quelet's description, but in the examples from Pin Hole Cave many were apparently branched, up to twenty *Stilbella* fructifications occurring as short lateral branches of a long central stalk. On examination it was found that the central stem was really a *Hirsutella* clavæ, and that the brown mycelium on the insect was *Hirsutella* mycelium, bearing typical *Hirsutella* conidiophores and conidial clusters.

Thus Mr. Armstrong's specimens demonstrate that *Stilbella Kervillei* is not parasitic on insects, as was supposed, but is parasitic on another fungus, a *Hirsutella*, the latter being entomogenous.

As far as is known, neither *Stilbella Kervillei* nor the *Hirsutella* have been found except in caves.

Spicaria (*Isaria*) *farinosa* (Holms) Fr.—The large majority of the specimens from Pin Hole Cave consists of gnats, each enveloped in a greyish loose ball of mycelium. This mycelium bears a scanty growth of *Spicaria* conidiophores. On taking this into culture, the fungus proved to be *Spicaria* (*Isaria*) *farinosa*, the common *Isaria* of *Lepidoptera* in this country.

Sporotrichum Isariæ Petch.—Some of the balls of mycelium on the gnats are pale brown. This colour is due to the growth on them of another fungus, *Sporotrichum Isariæ*, which is parasitic on *Spicaria* (*Isaria*) *farinosa*. This fungus has been found previously in Yorkshire, Norfolk and Sussex.

Beauveria Bassiana (Bals.) Vuill.—This common entomogenous fungus was found on one fly from Pin Hole Cave. It is generally distributed throughout the world, and is the cause of the disease of silkworms known as Muscardine.

The Rodent Remains from the Pin Hole Cave.

By J. Wilfrid Jackson, D.Sc., F.G.S.

The rodent remains obtained by Mr. A. Leslie Armstrong, F.S.A., from the section excavated during 1933–34 readily fall into two main groups, a lower and an upper, according to the levels from which they come. Those submitted from the Lower Rodent-level, viz. 10 ft. to

13 ft., comprise the following species: *Lemmus lemmus* (L.) (very abundant), *Dicrostonyx henseli* Hinton (common), *Microtus ratticeps* (K. & Bl.) (one jaw at 11–12 ft.), *M. anglicus* Hinton (a few jaws), *M. arvalis* (Pall.) group (a few jaws), *Arvicola abbotti* Hinton (three jaws), and *Apodemus flavicollis* (Melch.) (= *lewisi* Newt.) (few jaws and skulls). The remains of Red Grouse (*Lagopus scoticus* Lath.) occurred at 10 ft., and those of Ptarmigan (*Lagopus mutus* Mont.) at 9 ft. 6 in. Rodent remains from the Upper Rodent-level, viz. 2 ft. to 5 ft., are as follows: *Lemmus lemmus* (L.) (few), *Dicrostonyx henseli* Hinton (common), *Microtus anglicus* Hinton (common), *M. arvalis* (Pall.) group (common), *Arvicola abbotti* Hinton (one jaw), *Apodemus sylvaticus* (L.) and *A. flavicollis* (Melch.) (common), *Evotomys glareolus* (Schr.) (five jaws), and *Muscardinus avellanarius* (L.) (two jaws). The remains of Red Grouse and Ptarmigan also occurred at these levels.

In addition to the two main levels, I have identified some rodent remains from 8 ft., as follows: *Lemmus lemmus* (L.) (two jaws), *Dicrostonyx henseli* Hinton (one skull), *D. gulielmi* (Sanford) (one skull), and *Arvicola abbotti* Hinton (one skull); also Red Grouse and Ptarmigan at 7 ft.

Among the remains of larger animals are those of Woolly Rhinoceros (2–11 ft.), Reindeer (6 in.–16 ft.), Horse (1–14 ft.), Bison (1–12 ft.), Giant Deer (9–12 ft.), Mammoth (6 in.–14 ft.), Hyæna (1–17 ft.), Lion (8–13 ft.), Bear (2 forms) (1 ft. 6 in.–15 ft.), and Alpine Hare (2–7 ft.).

The Dormouse (*Muscardinus avellanarius*) does not appear to have been previously recorded from British caves, though I possess unrecorded jaws from the Late Pleistocene cave-earth at Dog Holes Cave, North Lancashire. On the Continent several forms of Dormice have been recorded from the 'Upper Rodent' layer (Magdalenian) of the Schweizersbild Cave.

According to Mr. Armstrong, who has based his conclusions on the physical evidence and on the human artifacts, the levels 10 to 13 ft. (Lower Rodent-layers) antedate the first phase of the Maximum Glaciation of Britain (Mousterian). The level 8 ft. is placed immediately before the second phase of this glaciation, and the levels 2 ft. to 5 ft. (Upper Rodent-layers) are later than the second phase and earlier than the Magdalenian cold phase. Judging from the material submitted, the Arctic rodents were more numerous when the Lower Rodent-layers were being deposited and became scarcer at later stages.

DISTRIBUTION OF BRONZE AGE IMPLEMENTS.

Report of Committee appointed to report on the Distribution of Bronze Age Implements (Prof. J. L. Myres, O.B.E., F.B.A., *Chairman*; Mr. H. J. E. Peake, *Secretary*; Mr. A. Leslie Armstrong, Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox).

In accordance with the Committee's recommendation in its report last year (*Report Brit. Assn.*, 1933 (Leicester), pp. 300–1), the Council has authorised the deposit of the completed catalogue (which has hitherto been entrusted to the Society of Antiquaries) in the British Museum; the trustees have undertaken the custody and maintenance of the catalogue by the staff of the Department of British and Mediæval Antiquities; and the whole catalogue and other records of the Committee have accordingly been transferred to the British Museum.

The Committee has therefore now only to report the completion of a few remaining record cards by Miss M. Anderson, and the record of a few recent accessions to certain museums, and finds in private hands.

On the conclusion of its task the Committee desires to express its appreciation of the long and devoted labours of its secretary, Mr. H. J. E. Peake, to whose foresight and persistence the initiation and achievement of this permanent addition to archæological equipment were due. The close attention, the wide knowledge, and the tact, which such an enterprise entails can best be appreciated by those who have had some part in it, and will be long and widely recognised.

KENT'S CAVERN, TORQUAY.

Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern (Sir A. Keith, F.R.S., *Chairman*; Prof. J. L. Myres, O.B.E., F.B.A., *Secretary*; Mr. M. C. Burkitt, Dr. R. V. Favell, Miss D. A. E. Garrod, Mr. A. D. Lacaille).

The following report has been received from the excavators, for the season 1933–34:

'The excavation of Kent's Cavern was resumed on October 30, 1933, and continued weekly, in the "vestibule," up to May 28, 1934.

'This work has opened up an area of about 160 sq. ft. of floor space, nearly one-half of which is directly under the British Association's site of the "Black Band," a hearth of Magdalenian times, worked by William Pengelly between 1865 and 1880. The greatest depth to which excavation has been carried this season is 10 ft. 6 in. below the general floor surface—i.e. about 16 ft. below the old stalagmitic floor.

'Large fallen blocks of limestone have prevented rapid exploration, as blasting by explosives in the Cavern is objected to by the proprietors as causing annoyance and inconvenience to visitors, and the rocks have to be exposed and broken up by hand labour. Under and between these blocks of stone were found remains of large animals, many of them coated with a deposit of stalagmite and sometimes embedded in a very hard mixture of stalagmite and cave earth.

'The remains of animals usually found in the Cavern were present in good number, including those of horse, rhinoceros, deer, Irish deer, bear, fox, ox, badger, pine marten, and mammoth.

'Some of the most interesting finds this season were: three foot bones of deer, all articulating; three vertebræ of a large animal (? rhinoceros) in their proper anatomical relations, found embedded in stalagmitic material; a first phalanx of a human finger, found 2 ft. below the floor level; eight flint implements; a flint core, 3 in. by 2 in. by 2½ in., found at a depth of 13 ft. 6 in. below the original floor level; small tines of deer, probably used as borers, and a quartzite pounder.

'Our thanks are again due to the proprietors of the Cavern, Messrs. Powe and Son, for their continued assistance.'

(Signed) Frederick Beynon, Arthur H. Ogilvie.

The Committee asks to be reappointed, with a further grant to meet the expense of unskilled labour to remove sifted earth from the excavation.

AINU OF JAPAN.

Report of Committee, appointed to carry out research among the Ainu of Japan, on work done by Dr. N. Gordon Munro in Yezo between November 1933 *and May* 1934 (Prof. C. G. SELIGMAN, F.R.S., *Chairman*; Mrs. C. G. SELIGMAN, *Secretary*; Dr. H. S. HARRISON, Capt. T. A. JOYCE, O.B.E., Rt. Hon. Lord RAGLAN).

HAVING travelled over a considerable part of Yezo, Dr. Munro finds that among the Ainu at the present day there are differences in belief and ritual in different parts of the island. Two factors are probably concerned in these differences, one ancient, the other modern. (1) In the old days tribal conflicts were common; the Ainu do not seem to have been united under any central authority, and there was no general priesthood to establish a canon of belief or ritual. (2) The modern factor is brought about by the clash of culture between Ainu and Japanese, with the consequent change in the old mode of life of the majority of Ainu communities. Hunting on land being practically a thing of the past, the Ainu depend more than ever upon the river and sea for sustenance. No longer can they barter skins for necessities or luxuries, but are compelled to eke out a living by attending to horses, doing odd jobs and a little field cultivation, in which the women play a prominent part. Ainu shopkeepers are extremely rare, and carpenters, blacksmiths and suchlike are almost unknown. They have no opportunity to learn, and if they did the Ainu communities are mostly too poor to support them. Ainu psychology, too, is characteristic of a primitive folk in transition from unsettled occupations to those that demand patient application. A Japanese servant will usually stick to his or her work until finished, but ' my experience with several Ainu servants is that they are not interested in domestic work.'

Considering these two factors together, it is perhaps remarkable that there should be as much resemblance as there is between the Ainu of one region and another. Possibly the strict exogamy developed in ancient times favoured the general levelling of ideas and customs throughout the Ainu country.

In spite of the decay of the old mode of life among the Ainu, there are still a fair number of pure-blooded elders (*ekashi*) among the Ainu of the Saru district, much of the following information being due to an old *ekashi* of 80 years, and an accomplished ritual dancer, who does not drink, is as bright as a man of 40.

SOCIAL ORGANISATION.

Inheritance and authority are patrilineal and marriage patrilocal, at least many inquiries north and south yielded only this answer. Descent, however, is strictly matrilineal, and exogamy is or was rigidly enforced. The Rev. Dr. Batchelor has stated (*Ainu Life and Lore*, p. 15) that the family tie was stronger on the mother's side and that the brother of the mother was looked upon as the real head of the family. Dr. Munro's inquiries of at least a dozen *ekashi* in the Hokkaido, in various places, failed to obtain more confirmation than that the mother's brother had a voice, though not a decisive choice, in the selection of a husband for the daughter. In Saghalin, he was informed by two *ekashi* who had lived there, the mother's brother has still some authority over her children, and it is hoped to learn more about this by local investigation. Dr. Batchelor has also stated that

totemism existed, but the instances given scarcely seem supported by sufficient evidence, though there seems reason to believe that the Ainu are totemic. The fortunate discovery by Dr. Munro of a secret girdle worn by all Ainu women which no man is allowed to see, has provided a clue to positive knowledge of clan organisation and perhaps acceptable evidence for totemism.

While discussing magical measures against epidemic invasion, an *ekashi*, Rennuikesh, said that women, by waving their girdles, could restrain *pakkoro kamui* (demons of pestilence), conflagrations, and even tidal waves. He called these girdles *upsoro tush*, bosom or secret cord, and further inquiry revealed the fact that although he had never seen one it was stated in *upashkoma* (sacred traditions) that each kind of girdle was the gift of a special *kamui* (god, spirit), whence its magic potency. 'I then recalled that when my house was burnt out last year a distant group of women, dimly lighted by the blazing house, were waving their arms to chase the *wen kamui* from the village. Suspecting that they were then waving their girdles, I found that every Ainu woman here wears one. Cordial relations established through medical treatment of children and urgent cases, combined with gentle persuasion, gradually elicited frank information. I even obtained two specimens and had copies made in my house singly by women, and these were compared with a sufficient number of originals to make sure that they were faithful copies. To make a long story short, my investigation in this direction has been verified by genealogical records containing over 250 names. These genealogies, selected from a total of over 400 names because they contain some infringements of the still operative prohibitions against incestuous marriage, have been sent to Prof. Seligman, who taught me the application of the genealogical method in elucidating social relations.'

Before stating the main conclusions derived from these genealogies, some further information concerning the girdle must be given. The usual and more polite term for this is *upsoro kut*, 'secret belt or girdle.' In ancient traditions it is called *a-eshimukep*, or honourable (esteemed, revered) hidden thing. Each Ainu woman cherishes the belief that the length of cord is an invariable measure of identity given by a particular deity to a remote ancestress. Comparative measurements, however, show some difference between the lengths of cord attributed to one *kamui*. This is only what one would expect, seeing that an arm's length is the standard. Ainu women, too, do not discuss their *kut* between each other, and rarely see another *kut* outside of the family. Their confidence, therefore, is unabated, all emphatically declaring that the length and pattern are completely identical. The varieties examined up to date are attributed to: (1) *Kamui Fuchi*, who is generally recognised as authorising other *kamui* to bestow it; (2) *Kimun kamui*, a female bear, who, taking human form, married an Ainu; (3) *Horokei kamui*, wolf—female, of course, like the others; (4) *Rep-un kamui*, in all probability a grampus, chief sea deity, whose sister married an Ainu; (5) *Isepo-kamui*, the hare, given tentatively as insufficiently investigated. Others heard of, but not seen, are the fox and deer.

Dr. Munro arrives at the following conclusions, combining the criterion of the *upsoro kut* with results obtained by the genealogical method. He considers these two lines of evidence so mutually confirmatory as to render his conclusions quite definite.

(1) It was forbidden to marry anyone of the same *upsoro kut*, the objective criterion of the clan. For those daring to infringe this prohibition the penalty was formerly death. Later it was mitigated to a fine, with compulsory alteration in the *kut*, apparently by reducing the number of folds in the cord, i.e., shortening the length of the distinctive line. Now, under

Japanese law, marriages occasionally occur, but are disapproved by relatives and members of the village and regarded as bringing ill-luck not only to the parties concerned but perhaps to the community.

(2) Formerly the levirate was a general custom, signified by a special name, *matraie* or *matraire*, 'wife-uplifting,' confined to this custom. Owing to poverty, more independence of women in tilling fields, and perhaps prevalent alcoholism of men, the levirate is no longer in vogue.

(3) Two brothers might not marry two sisters—they were one flesh in the bond of the *kut*. Strict injunction against it is pronounced in the sacred traditions. In a genealogical list of upwards of 250 names there were five cases of such union. Though permissible in Japanese law, these cases of double marriage of brothers and sisters were a scandal in their villages.

(4) The sororate was forbidden.

(5) Marriage with a deceased wife's sister is said to have been forbidden formerly ; it is now unpopular.

(6) Parallel cousins when children of two brothers could marry, but not the children of two sisters.

(7) Cross-cousins could marry, unless, as might possibly happen, their mothers had the same *upsoro kut*, say of the wolf clan. In this district, however, cousin marriage is not conspicuous. In 98 marriages of the total genealogical list prepared, only two cases of such marriage occurred, both cross-cousins.

(8) Uncles could not marry their nieces, nor aunts their nephews.

The *upsoro kut* has been prominently treated here because it is the one criterion whereby the Ainu decide all questions of marriage. Clan kinship does not in fact imply unadulterated lineage. During the last fifty years or more, the Ainu have adopted poor Japanese children, girls taking the *kut* of their new mothers. This is not because the Ainu are infertile. Rather, it appears, it is because they have been impressed with the idea that the Japanese are so much superior. Orphan Ainu girls, too, when adopted into another family take the *kut* of their new mother, after due solicitation and offering to *Kamui Fuchi*, to whom pertains authority in such matters.

Religion.

On first acquaintance there seemed to be considerable difference between the religious beliefs and rites of north and south. There is the same fundamental generalisation of *ramat*, conceived either as spirit personality or (less definitely) as purposive potency. Everything is inter-penetrated by *ramat* in some degree : whether quiescent or quick, whether acting from spontaneous impulse or subservient to more personal *ramat* known as *kamui* can usually be decided by what it does. The word *kamui*, however (*ka*, above, over), is applied not only to the supernatural but to anything extraordinary or superb, *Ramat* and *kamui* express the quintessence of Ainu religion, while the *ekashi*, or elder, is at once priest and shaman.

All Hokkaido Ainu employ the same means in soliciting and gaining the goodwill of the *kamui*, viz., *innono-itak*, or sacred talk, mainly invocation, *achikka*, libations, *shinurappa*, when offering to the dead, and—most important—*inau*. In the southern districts about twenty varieties of *inau* (sacred wands), the description of which would occupy much space, were examined and photographed. One noteworthy point is that for each kind of *kamui* a definite number of one or more kinds of *inau* are prescribed. In this respect there is little difference in any of the southern *kotan* (villages) visited. Though the northern *kotan* are less familiar, there seems to be a little more difference in the numbers allotted, while the *inau* themselves are

notably different. At Nibutani, Piratori, Mukwa, and Shiraoi, it is possible to tell at a glance what *kamui* are betokened by the number, kind, and position of *inau* at the *inau-san* shrine.

The *inau*, which may perhaps on occasion take the place of living sacrifice, appear to be especially associated with the *ramat* of Ainu ancestors. For defence against certain kinds of *wen kamui* (evil spirits), they are mobilised in companies of six, each with its chief, *sapane guru*, armed with a sword, represented by a slip of wood. Among many kinds of trees selected for *inau*, the willow, as a tree of life, is prominent. *Shutu inau* are made of willow when stuck in the corners of the hearth, sacred to *Kamui Fuchi*, divine ancestress and deity of the home fire, through whom all communications with the dead are made.

Besides the domestic *kamui* are 'those without,' the good—i.e. useful—deities of the *inau-san* or outer shrine, or altar. Here we encounter much difference between those of north and south, and some difference between those of different villages.

In some of the northern villages it was rather surprising to find that the sacred (ceremonial) window, *rorun puyara*, at the head of the hearth is not oriented invariably towards the east, as in southern districts, but faces the direction of current in a river, the assumed source of a food supply. As if to compensate for inattention to the rising sun, there is more regular worship of the sun at the *inau-san*, *inau*-shelf or fence, the family altar everywhere situated outside the sacred window, whence the *ramat* of beneficent *kamui* communicates with *Kamui Fuchi* at the hearth and gives help and comfort to the inmates.

Amongst various interesting magico-religious expedients already fading away, mention should be made of the bull-roarer, recorded by Dr. Munro at Shiraoi fifteen years ago.

Finally—lest this report grow over-long—it should be mentioned that Dr. Munro took from dictation about 70 or 80 *innono-itak*, for which the word 'prayer' seems not inappropriate. Most of the *innono-itak* are as logical, on the given premises, as the prayers of higher religions, and as apt to vary as the latter do outside of a prayer-book.

BLOOD GROUPING.

Report of Committee appointed to investigate blood groups among the Tibetans (Prof. H. J. Fleure, *Chairman*; Prof. R. Ruggles Gates, F.R.S., *Secretary*; Dr. J. H. Hutton, C.I.E., Mr. R. U. Sayce).

During the past year arrangements were made for obtaining blood groups of Tibetans. A small quantity of serum was sent from England for testing the serum produced by the Haffkine Institute in Bombay, India. A quantity of tested serum was then sent from India to the Medical Officer at a hospital in Gyantse, Tibet, but the results have not yet been received. A few results have been received, together with photographs, of tests made on Eskimos by a Canadian expedition to Pond's Inlet, Baffin Land, in 1931. These are of greatest interest in showing that the blood groups confirm the evidence of crossing with Europeans obtained from the photographs. Serum sufficient for testing 200 has been sent to the Canadian Government Expedition which recently sailed from Montreal for Hudson Bay to study the inland Eskimos in the tundra region west of Hudson Bay.

These people were considered by Rasmusson to represent the most primitive Eskimos, and unlike many of the coastal Eskimos they have had very little contact with civilised peoples. When opportunity arises through some expedition it is hoped to be able to obtain the blood groups of the Congo Pigmies, because their blood grouping should throw definite light on the relationship of the pigmies to the negroes.

PEN DINAS HILL FORT, CARDIGANSHIRE.

Report of Committee appointed to co-operate with the Pen Dinas Excavation Committee in the excavation of Pen Dinas Hill Fort, Cardiganshire (Dr. CYRIL FOX, *Chairman* ; Mr. V. E. NASH-WILLIAMS, *Secretary* ; Prof. V. GORDON CHILDE, Prof. C. DARYLL FORDE, Rt. Hon. Lord RAGLAN, Dr. R. E. M. WHEELER).

THE second season of archæological work on Pen Dinas, an Iron Age Hill Fort half a mile south of Aberystwyth, Cardiganshire, began on August 6 last, and will be concluded on or about September 15. The funds available, including the British Association's grant of £25, are being expended almost entirely on labour, since the equipment has been obtained by loan from various bodies and individuals. Eight workmen are being regularly employed at a wage of 35*s*. per week, so that the British Association grant has covered the cost of nearly two of the four working weeks that are almost completed.

The southern area of the main fortress is being investigated this year. It has been found that the eastern ramparts formerly curved round to enclose the main (or southern) fortified area on the north, and a strong walled bank, originally some 12 ft. high, was fronted by a 7-ft. ditch and counterscarp bank.

At a later date the greater part of a lower lying plateau to the north was fortified by bank and ditch on a rather smaller scale and linked to the main fortress. At about this time a gap was driven through the main defences to give access to this area. On the lower rubble of the breached walls and over the filled ditch an incurved entrance, with a triple series of gate-posts, was constructed. This formed an inner gate to the fortress, which had to be reached by an outer entrance through the lower fortification of the northern extension. This outer entrance was as first constructed a wide (40-ft.) gap, with semicircular walling, possibly an open driveway for livestock. At a later period, however, this gap was narrowed to 14 ft. by extending the bank and walling from either side, and post holes suitable for heavy swing gates and a bridge were set up at the corners.

A rectangular guard-house or dwelling-house, delimited by post holes, a packed earth floor, and slab hearth, has been found immediately within and to the south of this later outer gate. Finally, a third period of construction has been found at this gate in which the bank was heightened and extended on the outer side to the south. This extension covered the old ditch, and a second rock-cut ditch was in consequence constructed further east.

Numerous flint flakes as well as iron and bronze fragments have been found, but no pottery has so far been discovered.

VOCATIONAL TESTS AND ABILITIES.

Report of Committee appointed to develop tests of the routine manual factor in mechanical ability (Dr. C. S. Myers, C.B.E., F.R.S., *Chairman*; Dr. G. H. Miles, *Secretary*; Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear).

Work has progressed along the following lines as laid down in last year's (final) report of the Committee appointed to inquire into the factors involved in mechanical ability :

(1) The development of new manual tests with a view to simplifying and improving the measurement of the manual factor in assembly work.

(2) The devising of new methods of administering the tests of mechanical aptitude, with a similar aim in view.

(3) The development of easier tests of mechanical aptitude with a view to its measurement in elementary school children.

(4) The devising of new tests of mechanical aptitude with a view to the further analysis of the mechanical factor.

Data have been collected from the top two classes of an elementary school and from six forms of a junior technical school. Its statistical analysis is in progress.

It is hoped that the Association will continue to support the work along the lines suggested in Part III of this report, by renewing, and if possible increasing, its financial grant.

I. The Position at the Beginning of the Year.

The results reported to the Association up to the beginning of the year may be briefly stated as follows :

(*a*) *The factors involved in assembling work.*—Ability at the assembling operations investigated depends on two or more of the following factors, according to the particular operation :

(1) A small general factor (' intelligence '), which is more evident in the *mechanical* assembling tests, and in the more complex of the routine assembling operations, and which tends to disappear from the less complex routine assembling operations and from simple tests of manual dexterity.

(2) A ' mechanical ' factor, identified with the ' m ' factor in non-manual tests of mechanical aptitude, which is most conspicuous in the mechanical assembling tests, which tends to enter to a small extent into the more complex of the routine assembling operations, and which tends to disappear from the simpler of these operations.

(3) A ' manual ' factor, which enters most conspicuously into the more complex of the routine assembling operations, to an obvious, though less, extent into the less complex of these operations and into the simple manual tests, and which tends to disappear, as a group factor, from the mechanical assembling tests.

(4) A factor specific to each operation, which plays a larger part in the simpler operations, and diminishes in importance as the operation becomes more complex.

(*b*) *The measurement of the factors.*—(1) The mechanical factor is best measured by the non-manual tests of mechanical aptitude. Of the mechanical assembling tests, the more difficult ones provide the better measure.

(2) The manual factor is best measured by the more complex of the routine assembling tests. The measures afforded by the simpler manual tests are largely specific in character.

(c) *The reliability of the tests.*—The reliability of the various measures employed in the research was investigated in detail. The coefficients were found to be generally high. Where the manual tests were concerned, reliability was found to depend upon the number of repetitions of the operation constituting the measure of ability rather than on the length and complexity of the operation ; and was found to be independent of the stage of practice attained by the group measured. The routine assembling tests were found to predict the ability to which a subject would attain, after practice, to about the same degree of accuracy as they measured his present ability (0·7–0·9).

(d) *The transfer effects of practice and of training.*—An extensive investigation into the effects of (i) practice, and (ii) training, was also carried out. It showed that the effects of uninstructed practice at any one of the routine assembling operations failed to transfer to any of the other operations, whereas a course of training, involving exercises based on one of the routine operations produced effects which transferred to each of the other operations.

II. The Past Year.

Work during the past year has progressed along the following lines :

(a) *Further statistical analysis of the data.*—The saturation of the various groups of tests with their respective factors has now been determined as follows, from data obtained from sixty elementary schoolboys :

Two non-manual mechanical aptitude tests *v.* the mechanical factor (m), 0·80, 0·71 ; together, 0·83.

Ditto *v.* the general factor, 0·39, 0·36 ; together, 0·40.

Three mechanical assembling tests *v.* mechanical factor, 0·39, 0·63, 0·51 ; together, 0·73.

Ditto *v.* general factor, 0·13, 0·42, 0·23 ; together, 0·31.

Five more complex routine assembling tests *v.* manual factor, 0·56, 0·65, 0·48, 0·37, 0·61 ; together, 0·80.

Ditto *v.* general factor, 0·35, 0·14, 0·27, 0·25, 0·16 ; together, 0·34.

Four less complex stripping tests *v.* manual factor, 0·26, 0·61, 0·32, 0·33 ; together, 0·60.

Ditto *v.* general factor, 0·23, 0·09, 0·30, 0·20 ; together, 0·32.

Similar determinations, with very similar results, have been made from data obtained from thirty-six elementary school-girls.

(b) *Development of new tests.*—It was decided last year to concentrate on methods of measuring the group factors which the data had disclosed. To this end, the following new tests have been devised :

(1) *Non-manual tests of mechanical aptitude.*—Diagram booklets have been prepared for use in conjunction with the ' models ' type of mechanical test, so that the subject's response may now be obtained in the ' selective ' manner.

Two new sets of easier models have been devised and constructed for use in the upper classes of elementary schools. These also involve the use of a specially prepared booklet.

(2) *Tests of the manual factor.*—Six new manual tests, of the routine type, involving assembling and stripping, have been constructed. These involve various methods of winding and unwinding string from nails and of threading string through beads and through eyes screwed into a board. They

aim at increasing the saturation of the test with the manual factor by increasing the number of repetitions of the operation possible within a given time, and at simplifying the administration of the test and reducing random errors.

(3) *Paper-folding tests.*—Two new tests of the paper-folding and cutting type have been devised with a view to the further analysis of the mechanical factor, and the possible provision of a more direct method of measuring it.

(*c*) *Collection of further data.*—The new tests have been given to the top two classes of a boys' elementary school, and six forms of a junior technical school. These subjects have taken, in addition, the 'inventive' forms of the mechanical aptitude tests, and four of the routine manual assembling tests which were employed in the work reported last year; also tests of general intelligence.

The statistical analysis of these very extensive data is still in progress. Reliability coefficients have now been calculated for most of the tests, and indicate high reliability. This, and the keenness shown by the boys in doing the tests, suggests their suitability as tests of specific ability. The necessary inter-correlational studies for determining how far the factors in these new tests are the same as those found in the data formerly collected, and how far they may be 'saturated' with such factors, are still in progress. From the point of view of scoring, and ease of administering, the new tests are a very great improvement over the older ones.

III. Future Work.

It will be evident from Part II of this report that the most pressing thing now is to complete the analysis of the data that have been collected during the past year. The results thereby obtained may be expected to shed important light on the practical measurement of the 'mechanical' and the 'manual' factors. It may also extend our knowledge of these factors, and possibly disclose other important vocational 'abilities' associated with the new 'mechanical' and 'manual' tests, as well as throw light on the general principles of test construction.

When this aspect of the work is completed, there are many other fruitful lines of research opened up by the results reported by this Committee last year. In particular, the extension of the methods of training employed in the 'training' experiment would appear to lend themselves to valuable extension to many other forms of manual skill.

It is hoped that the Association will render the continuance of this work possible by renewing, and if possible increasing, its financial grant.

ANATOMY OF TIMBER-PRODUCING TREES.

Report of Committee on the Anatomy of Timber-producing Trees (Prof. H. S. Holden, *Chairman*; Dr. Helen Bancroft, *Secretary*; Prof. J. H. Priestley, D.S.O.).

Two papers on the structure of the monotoid timbers—'The wood anatomy of representative members of the Monotoideæ' and 'New material of *Monotes Kerstingii* Gilg from the Gold Coast'—have been completed and accepted for publication in the *American Journal of Botany* and the *Kew Bulletin*, respectively.

The investigations show that

(1) So far as wood anatomy is concerned, the Monotoideæ are a very coherent and somewhat circumscribed group.
(2) The wood anatomy of the group indicates a much closer affinity to the Dipterocarpaceæ than to the Tiliaceæ or any other group.
(3) The structure and properties of monotoid timbers are such that their cultivation for economic purposes cannot be advocated, although the timbers may be useful on a small scale locally.

Detailed investigations of new monotoid material are in progress; and work has been commenced on the systematic anatomy of the genus *Ulmus*, in order to throw some light on the problem of the identity and relationships of the British Elms.

The Committee asks for reappointment, with a further grant of £10.

FOSSIL PLANTS AT FORT GREY.

Final Report of Committee on Fossil Plants at Fort Grey, near East London (Dr. A. W. Rogers, F.R.S., *Chairman*; Prof. R. S. Adamson, *Secretary*; Prof. A. C. Seward, F.R.S.).

The investigations undertaken by the Committee have now been completed. The results have been published in a paper in the *Annals of the South African Museum* (vol. xxxi, pt. 1, p. 67, 1933). A set of the specimens collected has been deposited in the South African Museum at Cape Town.

The Committee desire to express their appreciation of the assistance granted towards the work. They do not ask to be reappointed.

EDUCATIONAL RESEARCH.

Report of Committee appointed to consider and report on the possibility of the Section undertaking more definite work in promoting educational research (Dr. W. W. Vaughan, *Chairman*; Miss Helen Masters, *Secretary*; Mr. E. B. R. Reynolds, Mr. N. F. Sheppard).

The Committee met in January. Dr. W. W. Vaughan, Miss H. Masters, and Mr. N. F. Sheppard were present.

The meeting decided that individual members should get in touch with other bodies interested in educational research. This has in many cases been done.

The general nature of the problem was discussed, and notes made thereon.

Prof. Hamley was proposed for co-option: he has been approached and has accepted.

The Committee considers that its activities are reflected in the programme of the 1934 meeting.

QUANTITATIVE ESTIMATES OF SENSORY EVENTS.

Second Interim Report of Committee appointed to consider and report upon the possibility of Quantitative Estimates of Sensory Events (Prof. A. Ferguson, *Chairman*; Dr. C. S. Myers, C.B.E., F.R.S., *Vice-Chairman*; Mr. R. J. Bartlett, *Secretary*; Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Dr. S. Dawson, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houston, Dr. J. C. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, Dr. R. H. Thouless, Dr. W. S. Tucker).

(1) Experimental investigation of matters at issue and research into the records of previous work have been continued by or under the supervision of members of the Committee.

(2) Theoretical discussion of the problem has been continued by means of reports from members of the Committee. These reports have been multiplied by the kind assistance of the British Psychological Society and have been circulated to all members of the Committee.

(3) Critical comments on certain of these reports have still to come in. It is hoped that they will be received by the autumn of this year, when the Committee will meet to discuss various aspects of the problem disclosed in the documents received, with a view to drawing up a final report.

(4) The Committee asks to be reappointed without grant.

SECTIONAL TRANSACTIONS.

(For reference to the publication elsewhere of communications entered in the following lists of transactions, see end of volume, preceding appendix.)

SECTION A.
MATHEMATICAL AND PHYSICAL SCIENCES.

Thursday, September 6.

DISCUSSION on *The ionosphere* (10.0) :—

Prof. E. V. APPLETON, F.R.S.—*Introduction.*

In the absence of data derived from measurements *in situ*, such as are possible for the lower strata of the atmosphere, information concerning the nature of the ionosphere (80 km. and above) is derived from ground observations on (1) terrestrial magnetism, (2) luminous manifestations such as the auroræ, meteorites, etc., and (3) wireless wave exploration. Although the first indications of pronounced upper-atmospheric ionisation came from (1), the prosecution of (3) has proved, on the whole, the most fruitful. Wireless methods possess the marked advantage in that an exploration can be made at any time and it is not necessary to wait for natural sequences or irregularities.

Wireless exploration consists in projecting waves (usually) vertically upwards and noting the characteristics of the returned energy. The quantities measurable are (*a*) the time of flight on the up and down journey, (*b*) the polarisation and phase changes, and (*c*) the intensity of the returned waves. Each type of measurement has been made to yield information. From measurements of (*a*) at different wave-lengths the somewhat complicated structure of the ionosphere has been broadly worked out and its temporal variations studied. From (*b*) conclusive evidence has been derived that free electrons exist throughout the whole of the ionosphere and are active electrical agents in causing the deviation of the waves ; while from (*c*) the frictional effect of air pressure on the free electrons may be estimated.

Regular features.—The ionosphere is divided into two main divisions, Region E at an equivalent height of 100 km. and Region F at an equivalent height of 230 km. and above. In both regions the ionisation is replenished daily at a rate dependent on solar altitude, and during the night steadily decreases. (During the day a lower ' shelf ' is also formed on the main Region F.) The diurnal and seasonal variations are such as can be explained by assuming solar ultra-violet light as the ionising agency and recombination of electrons and ions as the dissipative influence.

Irregular features.—(*a*) There is often formed a thin reflecting sheet of ionisation about the height of Region E. This may occur by day or night. Possible influences to be discussed in connection with the origin of this ' Abnormal Region E ' are :

(1) Extraneous ionising agencies (e.g. solar corpuscles and terrestrial thunderstorms).
(2) Horizontal motion of ionisation from more densely ionised regions by winds or diffusion. (The coefficient of lateral diffusion may be shown to be a maximum at about 100 km.)
(3) Readjustment of ionisation already present due to tidal or thermal influence, bringing about a sharper gradient of refractive index at a particular level and thus giving rise to quasi-reflection as distinct from the normal deviating process.

(*b*) The maximum ionisation content in Region F is often found to increase during the night. Possible influences to be considered are :

(1) A nocturnal ionising agency.
(2) Readjustment of ionisation distribution due to cooling and shrinkage of the atmosphere causing an increased electron concentration.

(*c*) Very occasionally there are found subsidiary regions of ionisation (1) between Regions E and F, and (2) above the main Region F. These have been noted at both the Slough Radio Research Station and at the Halley-Stewart Laboratory, Hampstead.

Freak wireless transmissions.—A careful watch was now being kept each day on what might be called the weather conditions in the ionosphere. Such work was being carried out at the Slough Radio Research Station and at the Halley-Stewart Laboratory at Hampstead. As often happened in the study of geophysical phenomena, abnormal events proved of special interest and importance. Both of the ionised regions were found to exhibit, occasionally, increases of ionisation even at night, when ultra-violet light from the sun could not possibly be reaching the upper atmosphere.

In 1930, during some experiments carried out at King's College, London, curious increases of ionisation were noted in the lower of the two regions (the so-called Kennelly-Heaviside Layer). There appeared to be some influence maintaining and even increasing the ionisation which normally decreased during the night. The same effect had since been noticed in different parts of the world. He wished to put forward the theory that this abnormal ionisation, which he had found gave almost mirror-like reflection of the waves, might be responsible for the freak transmissions which had been noted from time to time in long-distance transmission.

It had also been found that there was a fairly definite limit in the short wave-length range below which one could get only a quasi-optical range. Waves shorter than the limiting value (8 to 10 m.) usually pierce the ionosphere and leave the earth altogether. But calculation showed that under the abnormal conditions mentioned, which appeared to be connected in some way with both thunderstorms and magnetic storms, the limiting wave-length should be less than its usual value.

Mr. J. A. Ratcliffe.

Collisions between electrons and neutral molecules cause absorption of a wave travelling through the ionosphere. From observation of the resultant absorption deductions may be made about the frequency of collision of the electrons.

Calculation shows that a region of absorption may be situated below the region of deviation of the wave, the extent of the absorbing region being determined by the height distribution of the electron collisional frequency. There is no need to postulate a lower ' layer ' of ionisation to explain this

region of absorption. The existence of such an absorbing region is required to explain the absorption observed at different distances from a transmitter.[1]

Absorption of a wave near the top of its trajectory is related to the group retardation there, and from a comparison of the observed magnitudes of these quantities we deduce that the collisional frequency in the F region is about 5×10^3 per second, and in the E region is about 2×10^4 per second. The extra group retardation of the ordinary wave on a wave-length of 60 m. in the day-time perhaps explains why Eckersley[2] found it to be weaker than the extraordinary wave.

To explain some unexpected results it has been suggested[3] that absorption determines the greatest frequency which may be reflected from the F region at midday in summer, whereas in winter the maximum electron density determines this critical frequency. If this is the case, then the temperature of the F region at a summer midday must be considerably greater than that at a winter midday.

Automatic records have been taken showing how the height of reflection of wireless waves of a fixed frequency varies with the time of day. These records show the occurrence of intermittent reflections from a height of about 105 km.—that is, below the ordinary E region. Such reflections may occur by night or by day. They are presumably due to some 'abnormal' source of ionisation. A statistical analysis indicates that they are probably related to the occurrence of (*a*) magnetic storms, and (*b*) thunderstorms. The opportunity of observing on a series of different frequencies in rapid succession occurred recently, during a thunder shower. During the shower wave-lengths down to 45 m. were reflected (partially) from a height of 105 km., whereas half an hour before and a quarter of an hour afterwards there were no reflections from regions below 250 km. (F region) on any wave-length shorter than 75 m. It appears as though the thunder shower had produced ionisation at a height of about 105 km.

Mr. R. Naismith.—*The polar ionosphere.*

It has been shown by Appleton that the main ionising agency for the E and F regions of the ionosphere in temperate latitudes is the ultra-violet light from the sun.

It has also been suggested by Chapman that charged particles emitted from the sun may produce ionisation in the upper atmosphere, and the phenomenon of the aurora appears to confirm this theory.

Observations made by the British Wireless Expedition during the second International Polar Year are examined with regard to these two theories. The first of these theories is examined with reference to the whole year's observations, but more particularly under the special condition existing in the Polar regions in the winter when no ultra-violet light from the sun is reaching the earth, and in the summer during the period of the midnight sun.

The maximum ionisation effects of charged particles are to be expected in northern latitudes. This theory is also examined with reference to the year's observations, but more particularly during periods of magnetic disturbance.

There is at present no unanimity of opinion on the relative importance of these two influences, but the present series of observations appear to indicate that both are necessary.

[1] *Proc. Roy. Soc.*, A, **115**, 291 (1927). [2] *Ibid.*, A, **141**, 710 (1933).
[3] *Proc. I.R.E.*, **22**, 499 (1934).

Prof. R. H. Fowler, O.B.E., F.R.S., and Mr. G. B. B. M. Sutherland.—*The specific heats of simple gases at high temperatures* (11.30).

When, some seven or eight years ago, analysis of the quantum states of simple molecules had advanced sufficiently far to be applied with confidence to the calculation of the specific heats of the simple gases, it was found, to the surprise of almost everyone concerned, that the accepted values at high temperatures were in striking disagreement with the theory. The disagreement begins to make itself felt, for example, for oxygen and nitrogen just above room temperatures. This discrepancy has since then been much studied from two points of view—first, to re-examine the specific heats by new methods and to see if they could be brought into agreement with theory; and, secondly, to understand the meaning of the older measurements, which cannot be dismissed as being merely in error. Both these studies have now been successful. The discrepancy between theory and the older observations has been shown to be due to the very slow interchange of vibrational energy in rather rigid molecules such as oxygen and nitrogen with the translational and rotational energy.

Mr. J. M. Stagg.—*The British Polar Year Expedition to Fort Rae, N.W. Canada, 1932–33* (11.55).

Throughout the thirteen months ending August 31, 1933, upwards of forty countries co-operated in a world-wide organisation for intensive observations in meteorology and such allied fields of investigation as terrestrial magnetism, aurora and atmospheric electricity. During this period probably over sixty special stations and expeditions, many of them in high northern latitudes, participated in the general programme. As part of Britain's share in this International Polar Year an expedition of six men was sent to reoccupy the station at Fort Rae on the Great Slave Lake, N.W. Canada, held half a century ago by the First Polar Year Party.

The objects of the expedition included the collection of complete and continuous observations of the main meteorological elements both on the surface and into the stratosphere, procuring continuous records of the variations in the earth's magnetic field, and gathering as much information as possible about auroral phenomena in that part of Canada. Photographs of aurora from two base stations, so that its position in space could be determined, were specially wanted. Measurements were also to be made of the various elements of the atmospheric electrical field near the surface at Fort Rae.

To attain these objects in the somewhat extreme conditions of N.W. Canada special methods and safeguards had to be employed.

The photography of aurora called for a means of continuous communication over the 25 km. separating the main base and substation; 4,700 simultaneous pairs of photographs were taken, of which 75 per cent. are probably suitable for measurement.

The reduction of the data brought home by the expedition is now in an advanced stage of preparation. But the work of adequate discussion and co-ordination with the data for all the other Polar Year stations will be a matter of several years.

Prof. G. W. O. Howe.—*The rotating field of a cylindrical bar magnet—a perennial chimæra* (12.25).

From time to time the question is raised: Does the magnetic field of a cylindrical bar magnet rotate with the magnet? This question is meaning-

less ; the misconception which gives rise to it is due to the lines of force being endowed with a physical reality for which there is no justification. When the bar magnet rotates the electrons within it move relatively to one another through magnetised space and thus experience forces, but no meaning can be attached to the movement or non-movement of the magnetic condition of space which undergoes no change in magnitude or direction. The statement recently made by Prof. Cramp, that Faraday's description of an experiment was lacking in detail because ' he omitted the possibility of the e.m.f. being produced by a rotating magnetic flux cutting the stationary parts of the circuit,' is unfair to Faraday, who could hardly be expected to foresee that such a queer misconception would subsequently arise. Prof. Cramp admits after making about fifty (!) experiments that they are inconclusive, as indeed they must be since they were designed to answer a meaningless question. Lines of force and tubes of magnetic induction are mathematical fictions : there is nothing material about them, nor do they represent discontinuities in space, which could be earmarked in order to detect their movement. Their number is a mere convention.

Friday, September 7.

PRESIDENTIAL ADDRESS by Prof. H. M. MACDONALD, O.B.E., F.R.S., on *Theories of Light* (10.0). (See p. 19.)

Dr. F. W. ASTON, F.R.S.—*The roll-call of the isotopes* (11.0).

The word ' isotopes ' was first used by Soddy to indicate atoms having identical chemical properties but different mass which he discovered among the products of radioactivity. Their presence in ordinary stable elements was definitely proved later by the mass-spectrograph. Of recent years the word has altered its meaning and is now used to designate any atomic species. By the study of mass-spectra, supplemented in a few cases by that of optical spectra, the analysis of the common elements may now be regarded as fairly complete. The main isotopic constituents are known for all but four—palladium, iridium, platinum and gold. The accuracy of the data varies in a wide degree from element to element, the analysis being easiest technically for the inert gases, and most difficult for the rare earths and noble elements. Disregarding those of radioactive period less than one million years, the total number of isotopes now known is well over 240, about three per element. The isotopic complexity of elements of odd atomic number shows a remarkable regularity. Excepting hydrogen, none of these has more than two isotopes. On the other hand, elements of even atomic number may be much more complex, tin having as many as eleven isotopes, and it is an interesting speculation whether or not the number may be extended indefinitely by increasing the delicacy of the methods of detection.

DISCUSSION on *The structure of alloys* (11.30) :—

Prof. W. L. BRAGG, O.B.E., F.R.S.—*Introduction.*

We may conveniently define an alloy by two characteristics The first is the arrangement of the positions occupied by its metal atoms. A different geometrical pattern of the atomic sites characterises each phase of the alloy system, and is the essential feature which remains constant in a single-phase region although the composition of the phase may vary over a wide range. The second is the distribution of the atoms of each kind in a binary or

more complex alloy amongst the phase sites. This distribution varies of necessity as the composition varies, and may often be altered by thermal treatment although the phase remains the same.

Recent developments have indicated the possibility of discovering an adequate theoretical basis for the explanation of both characteristics. Broadly speaking, the first depends upon the interaction between metal atoms and free electrons, the second upon the relative potential energies of the ordered and disordered distribution of atoms amongst the sites.

Prof. G. I. Taylor, F.R.S.—*A theory of plasticity in crystals.*

In many metallic crystals the most remarkable features of plastic distortion are :

(1) its geometrical nature, the strain consisting of a shear parallel to a crystal plane ;
(2) the rapid increase with increasing plastic strain in the stress necessary for plastic flow.

A theory is developed which accounts for both these phenomena as consequences of the production and subsequent migration, under the influence of molecular agitation, of a special type of singularity in the structure to which the name ‘ dislocation ’ is given.

Reasons are given for believing that dislocations can migrate through the crystal at a temperature far lower than that necessary for the interchanges which occur when a metal is annealed or when an alloy changes from one phase to another.

In a perfect crystal structure a single dislocation might migrate freely, but the presence of other dislocations, each of which is surrounded by a field of elastic stress, will prevent the free migration of dislocations unless the shear stress externally applied is greater than that due to the integrated effect of all neighbouring dislocations. The stress necessary for plastic strain, now considered as due to migrating dislocations, therefore depends on the number of dislocations. A relationship is also found between plastic strain and the number of dislocations, so that the plastic stress-strain relationship is deduced theoretically.

Dr. H. Jones.—*Applications of the modern electron theory of metals.*

The electrical resistance of pure metals with reference to their place in the periodic table was discussed, and it was shown how the observed resistance of alloys leads to a better understanding of the resistance of pure metals.

The form of the Brillouin zones for a number of crystal structures associated with well-known metals and alloys was described and illustrated. The significance of the form of these zones in relation to the structure was considered with particular reference to the case of bismuth, and alloys possessing the characteristic γ and ε structures. From these considerations it was shown to be possible to find a theoretical basis for the well-known Hume-Rothery electronic rules.

Mr. A. J. Bradley.—*Atomic arrangement in alloys.*

The application of X-ray analysis to the study of alloys has yielded a great amount of fresh information impossible to be obtained by the older methods of metallography. The problem of differentiating between alloy phases and of determining phase boundaries has become much simpler,

while in many instances X-ray work has shown the presence of phases difficult to identify by other methods.

Each phase has a characteristic structure which in its salient features is the same for all alloys belonging to the phase, but a more detailed study shows that there are continuous structural changes on varying either composition or temperature. Recent improvements in technique have made it possible to follow the changes in lattice dimensions to an accuracy of 1 part in 50,000. Detailed changes in atomic arrangement, e.g. the formation of superlattices, may be followed quantitatively by means of X-ray intensity measurements. The results of all such investigations are found to fit in with the data obtained from measurements of magnetism, electrical conductivity and other physical properties.

Prof. G. P. Thomson, F.R.S.

Afternoon.

Visit to Natural Philosophy Department, Marischal College.

Monday, September 10.

Joint Discussion with Section B (Chemistry, *q.v.*) on *The preparation and properties of heavy hydrogen* (10.0).

Afternoon.

Visit to Braemar for unveiling of memorial to Johann von Lamont.

Tuesday, September 11.

Symposium on *Telescopes* (10.0):—

Mr. C. Young.—*The 74-inch reflecting telescope of the David Dunlop Observatory, Toronto University, Canada.*

The equatorial mounting of the telescope is of the modified English or composite type, in which the tube is carried to one side of the polar axis. This axis is built up of steel castings with forged steel pivots mounted in self-aligning ball bearings.

The driving circle is a steel casting with bronze rim, 8 ft. diameter, cut with 960 teeth.

The forged steel declination axis weighs over 3 tons and is mounted in ball bearings.

The tube comprises three parts :

(*a*) The centre portion, a steel casting about 7 ft. diameter.
(*b*) The upper, or lattice, portion constructed of duralumin ' I ' beams, with diagonal tension rods of duralumin.
(*c*) The mirror cell.

In the lower part of (*a*) an iris diaphragm is fitted allowing for a range of aperture from 12 to 74 in.

The driving clock comprises a crossed arm friction governor driven by a weight which is automatically kept wound up by an electric motor. The clock drives on to a gear plate incorporating a ' Grubb ' type seconds control.

All the motions of the telescope, viz. quick setting, guiding and clamping in both R.A. and declination, also focusing of the Cassegrain mirror, are electrically operated.

The main mirror, now being worked at Newcastle-on-Tyne, is of a special Pyrex glass, 76 in. diameter by 12 in. thick and focal length of 30 ft.

The Cassegrain mirror gives an equivalent focus of 108 ft.

The dome, which has a diameter of 61 ft. with an opening 15 ft. wide, is fitted with motor-driven shutters and wind screens, and carries an electrically operated observing carriage for use at the Newtonian focus.

The dome is mounted on a circular steel building 24 ft. high.

Mr. W. M. H. Greaves.—*The new 36-inch reflector at the Royal Observatory, Greenwich.*

Mr. C. R. Burch.—*On null systems for testing concave telescope mirrors.*

Zonal tests on concave specula have neither the accuracy nor the speed of null tests. The most delicate test—Prof. Zernike's phase-contrast test—is essentially a null test. We need a method of null testing paraboloids without using a full-size flat, and methods of null testing mirror curves other than conic sections—e.g. the Ritchey-Chrétien curve. The asphericity of a 36-in. paraboloid of F/4 can be compensated with one 9-in. concave spherical mirror, one $1\frac{1}{2}$-in. convex mirror aspherical by only $\frac{1}{8}$ wave-length, and one $\frac{1}{2}$-in. flat. For an F/6 paraboloid, both compensating mirrors may be spherical. Asphericities up to a few wave-lengths may be compensated by a figured transmission plate, checked with an optical flat—in this check the transmission errors are seen multiplied by 4. The figured plate may conveniently be 1 in. diameter: the star is decentred so that the light passes through it once only, and the consequent astigmatism is annulled by two plane-parallel plates placed with equal and opposite obliquities to the central ray. By placing the figured plate at different distances from the star, a range of paraboloids can be tested.

Mr. N. R. Campbell and Mr. C. C. Paterson, O.B.E.—*Photoelectricity, art and politics: an historical study* (11.30).

(Ordered by the General Committee to be printed *in extenso*. See p. 445.)

Wednesday, September 12.

Dr. W. H. McCrea.—*Observable relations in relativity* (10.0).

The formulation of an invariant which represents 'spatial distance,' as measured by some prescribed experiment, in the space-time of general relativity has been studied by E. T. Whittaker and others. Also E. A. Milne has emphasised the importance of interpreting any given space-time in terms of the 'world-pictures' of an observer belonging to it. In this paper it is shown how the apparent size, brightness, etc., of nebulæ in certain models of the 'expanding universe' can be calculated by fairly elementary methods. Thence one obtains, for example, the number of nebulæ in a given range of apparent magnitude, and the relation between apparent

magnitude and red-shift, which represent the type of relation which can be tested by observation.

Mr. H. G. HOWELL.—*Recent applications of spectroscopy* (10.30).

Now that the importance of the presence of small amounts of metallic impurities in alloys has been recognised, the practice of quantitative spectrum analysis is receiving much attention. The internal standard method involving a determination of intensity ratios is considered to be the most accurate, although for higher percentages of impurity the Barrett twin-spark method is preferable.

The intensity ratio can be measured conveniently by using a rotating logarithmic disc.

The biologist and medical research worker are using the spectrograph to determine the influence of minute traces of metals in the blood and spinal fluid, in plants and living organisms.

Absorption spectrophotometry is providing much useful data about the equilibrium of certain chemical reactions which cannot be obtained by chemical methods.

Absorption measurements have been of great importance in work on such obscure organic compounds as the vitamins. The spectra of hæmoglobin and its related compounds are being extensively studied with a view to correlate changes in spectra with changes in chemical constitution.

It has been reported that the absorption spectrum of the plasma of the blood of normal rats is different from that of those suffering from cancer, and that marked changes take place in the absorption curves at the approach of death.

DEMONSTRATIONS (continuously for the period of the meeting) :—

Mr. C. R. BURCH.—*Prof. Zernike's phase contrast test.*

An F/6 paraboloid is shown, the test being made null with the aid of a figured compensator. The errors of spherical aberration, coma, and astigmatism can be shown by changing the adjustments : zonal error can be shown by inserting a figured ' error-plate.'

Mr. L. H. J. PHILLIPS.—*Prof. Zernike's phase contrast method of microscopic illumination.*

The apparatus for this demonstration was kindly lent by Prof. Zernike.

DEPARTMENT OF MATHEMATICS (A*).

(Prof. E. T. WHITTAKER, F.R.S., in the chair.)

Thursday, September 6.

DISCUSSION on *The electronic theory of metals* (10.0) :—

Prof. R. H. FOWLER, F.R.S.—*The quantum theory of metals.*

General introduction. Electron distribution laws ; the Fermi function. Thermionic work function and photoelectric threshold of an ideal metal. The free path phenomena ; Sommerfeld's elementary discussion for an

ideal metal; conductivity; thermoelectric phenomena; the transverse effects in a magnetic field. Meaning of the sign of the Hall coefficient.

Next stages in the elaboration of the theory. Electron states in a periodic field of force. Brillouin's zones. Metals as insulators and semiconductors.

Prof. C. G. Darwin, F.R.S.—*The quantum theory of the free path* (10.50).

The formal free path of Sommerfeld's theory is replaced by a properly calculated free path by studying the interaction between the electron waves of an ideal metal and the elastic waves (thermal agitation) of the ionic lattice. Bloch's integral equation for the distribution function.

Dr. H. Jones and Prof. N. F. Mott.—*Further developments of the theory* (11.20).

The form of the Brillouin zones for a number of crystal structures associated with well-known metals and alloys is discussed and illustrated. The significance of the form of these zones in relation to the structure is described with particular reference to the case of bismuth, and alloys possessing the characteristic γ and ε structures. From these considerations a theoretical basis is found for the well-known Hume-Rothery electronic rules. The nature of the X-ray emission bands of metals discovered by O'Bryan and Skinner is discussed in the light of the Bloch theory. This leads to an examination of the optical transition probabilities from the conduction levels of the metal to the deep-lying K or L levels. A brief account of the optical properties of the alkali metals, including Zener's explanation of Wood's recent experiments, is given.

Finally, the electrical resistance of pure metals with reference to their place in the periodic table is discussed, and it is shown how the observed resistance of alloys leads to a better understanding of the resistance of pure metals.

Prof. G. P. Thomson, F.R.S.

Friday, September 7.

Discussion on *Unified field-theories in physics* (11.0):

Prof. E. T. Whittaker, F.R.S.—*The problem and some recent proposals for its solution.*

The problem to be solved. The earlier theories of Weyl, Eddington, Einstein, and Kaluza-Klein, compared with the more recent developments by Einstein-Mayer, Veblen, and Schouten-van Dantzig. Introduction of the fifth coordinate. Interpretation of the coordinates (i) in five-dimensional space, (ii) in four-dimensional space-time. Geodesics as world-lines of charged and uncharged particles. Interpretation of curvature. Deduction of the field-equations of gravitation and electricity.

Dr. W. H. McCrea.—*Unified field-theories and the quantum theory* (11.50).

The formulation of Dirac's wave equation in projective relativity; the physical significance of the result. Discussion of the general *a priori* possibility of including quantum theory in existing unified field-theories.

Alternative possibility of obtaining unified theory of gravitation and electromagnetism by treating them as statistical properties of systems obeying a quantum theory.

Dr. J. H. C. WHITEHEAD.—*Projective relativity* (12.10).

Generalised projective geometry, according to this presentation, depends upon the idea of a geometric object determined by sets of components and a transformation law. Whereas in affine geometry a geometric object (e.g. a scalar function or a contravariant vector) has one set of components in each coordinate system, a projective invariant has an infinity of sets of components. The transformation from one set of components to another in the same coordinate system can be explained in terms of a geometrical process analogous to projection in classical projective geometry. This explanation involves the use of an additional variable and, as when using homogeneous coordinates in the classical projective geometry of n dimensions, the formalism is that of $(n + 1)$-dimensional affine geometry.

The power of this treatment is largely due to the closeness with which the formalism copies the $(n + 1)$-dimensional affine and Riemannian theories. In particular this applies to projective relativity, and if the ideas referred to above can be elucidated it should not be necessary to introduce a great deal of formal detail in the discussion of relativity. It will probably seem best to concentrate the formal work into a derivation of the equations of motion of a charged particle. Taking for granted the formulæ which are obtained by the standard methods of Riemannian geometry, this should involve only a short calculation in the course of which many of the special features of the theory will be underlined.

Monday, September 10.

Prof. J. A. CARROLL.—*Some applications of Fourier transforms* (10.0).

(1) The equation

$$O(z) = a\int_{-1}^{+1} I(z + \beta t)g(t)dt \quad . \quad . \quad . \quad (1)$$

regarded as an integral equation for $I(z)$, can be solved 'operationally' by regarding z as an operator, and on writing down the equation of which (1) is the operational equivalent (image equation) and rearranging the terms, the operational form of the rearranged equation is the solution of (1), namely—

$$I(u) = \frac{1}{2\pi i}\int_{0}^{\infty} e^{-ux}\frac{1}{G(\beta x)}\int_{c} e^{-zx}\, O(z)dz\, dx \quad . \quad . \quad (2)$$

where c is a suitably chosen path, and

$$\frac{1}{a} = \int_{-1}^{+1} g(t)dt,\ G(\beta x) = a\int_{-1}^{+1} e^{-\beta tx}\, g(t)dt.$$

This enables the validity of solution of (1) by the elementary method of Taylor expansion of $I(z + \beta t)$ and reversion of the series obtained to be tested.

Solution of the form (2) is troublesome to use when $O(z)$ is known numerically for real values of the argument only. If $g(t)$ is assumed known,

it is possible to regard (1) as an equation for β, inasmuch as (1) is only possible (if, e.g., $I(x)$ is everywhere > 0) for a unique value of β, given $O(z)$.

By forming the Fourier transforms of both sides of (1) it is possible from examination of the zeros of the periodogram to find β, and by a second Fourier transformation to compute $I(z)$. For example, if $g(t)$ is $\sqrt{(1 - t^2)}$, the transform $\int_{-\infty}^{\infty} O(t) \cos ut\, dt$ must vanish whenever $u\beta$ is one of the zeros of $J_1(x)$; hence, since u is known at these zeros, β is determined.

(2) If the probability of a quantity having a magnitude between x and $x + dx$ is $f(x)dx$ in one 'measurement,' the probability of a sum s to $s + ds$ from n measurements is $f_n(s)ds$, where

$$f_n(s) = \int_{-\infty}^{\infty} f_{n-1}(s + t) f(t) dt.$$

The computation of $f_n(s)$, in successive steps, is very laborious, but if the transform $g(u)$ of $f(x)$ be constructed,

$$g(u) = \frac{1}{\sqrt{(2\pi)}} \int_{-\infty}^{\infty} f(t) \cos ut\, dt,$$

taking $f(-t) = f(t)$, then $f_n(s)$ is obtained rapidly and simply as

$$\left\{\sqrt{(2\pi)}\right\}^{n-2} \int_{-\infty}^{\infty} g^n(u) \cos ut\, du.$$

In illustration the method is applied to the probability of a given score after a given number of rubbers at contract bridge.

Incidentally the method offers a convenient proof of the theorem that the distribution function for errors the result of a large number of small errors tends to the Gaussian law as the number of independent sources of error tends to infinity.

Dr. W. L. MARR.—*Desargues configurations from a quintic curve* (10.50).

If P is a point such that the lines joining P to five fixed points are tangents to a cubic curve at these five points, the locus of P is a quintic touching the conic of the five points at these points and passing through the other fifteen points of intersection of the lines joining them. The quintic can, however, be defined uniquely, and more simply, by these contacts and incidences, instead of as a locus.

If six points are given on a conic, there are ten points P such that the lines joining P to the six points touch a cubic at these points. The ten points can be found as the relevant intersections of two quintics, but they can be shown independently to form the $10_3 10_3$ configuration arising in Desargues' theorem on perspective triangles, whence it follows that six quintics associated with six points on a conic have ten common points forming a Desargues configuration. If P is one of these ten points, three other of the points are on the polar of P for the conic. This result enables us to construct the configuration from one of the quintics and one of the ten points, and we find that the point can be chosen arbitrarily on the quintic—that is, that one quintic is the source of a single infinity of the $10_3 10_3$ configurations.

Mr. E. A. Maxwell.—*Some examples in the theory of surfaces* (11.10).

The paper gives an illustration by example of certain general properties of surfaces.

Denote by $F^{3\sigma}({}^0C^4)^\sigma$ a surface of order 3σ, having as σ-fold curve the rational quartic ${}^0C^4$ (of order four and genus zero). The canonical surfaces, defined in similar notation by $F^{3\sigma-4}({}^0C^4)^{\sigma-1}$, are invariant for birational transformation. Now the curve ${}^0C^4$ lies on a unique quadric φ, meeting the two systems of generators in three points and one point respectively; each ' three '-generator necessarily lies on a canonical surface, which therefore degenerates into φ, together with a variable part. The curve of intersection of φ with $F^{3\sigma}$ is Noether-exceptional (i.e. a *fixed* part of every canonical surface), and, in fact, consists of 2σ straight lines, generators of φ. In accordance with general theory, these may each be transformed to a simple point of a birationally equivalent surface:

The cubic surfaces through the curve ${}^0C^4$ may be represented by the prime sections of a threefold locus $V_3{}^5[6]$ of order five in six dimensions. The points of ${}^0C^4$ correspond to the generators of a rational ruled surface R^{10} of order ten on V; the ' three '-generators of φ correspond to the points of a conic c. The given surface corresponds to the surface of intersection of V by a primal of order σ; this latter meets c in 2σ *points*, each of which corresponds to a Noether-exceptional curve.

Similar results are given for the surface $F^{3\sigma}({}^2C^5)^\sigma$, the only other surface of this type.

Sir A. S. Eddington, F.R.S.—*Theory of electric charge and mass* (11.45).

The following principles (amongst others) are employed in the theory:

(1) *Indistinguishability.*—A system of two particles No. 1 and No. 2 is described dynamically by giving as a function of the time the probability distribution of two sets of coordinates, q, q', together with an interchange variable θ such that $\cos^2\theta$ is the probability that the particle at q is No. 1 When the particles are regarded as distinguishable (and always distinguished without uncertainty) θ is constrained to be zero. The Coulomb energy of electrons and protons is the momentum conjugate to θ.

(2) *Metrical Tensor.*—The tensor $g_{\mu\nu}$ giving the metric of macroscopic space must arise out of the fundamental conceptions of wave mechanics, and not as an extraneous datum. It is the energy tensor of the *a priori* or standard probability distribution of the particles. Since this distribution itself provides the metric of the space in which it is represented, the space automatically appears as uniform and isotropic.

(3) *Idealisation.*—The most elementary equations of quantum theory which contain the definitions of charge and mass refer to highly idealised conditions. Formally the ideal uniform conditions prevail throughout the universe, since if the momentum of a particle is prescribed, its position in the universe is entirely unknown. The equations therefore apply strictly to spherical space and to hyperspherical phase-space.

(4) *Curvature.*—Mass must arise out of curvature of space-time in quantum theory as it does in relativity theory. Curvature (by rendering space finite) limits the possible uncertainty of position, and therefore gives a minimum uncertainty and corresponding minimum expectation value of momentum.

(5) *Comparison Distribution.*—Observationally the effect of mass is manifested in the study of the combined probability distribution of a particle and a physical reference body, but mathematically mass is defined as a

coefficient in the simple probability distribution of the particle. The values of the masses of the proton and electron are determined by this substitution of a simple probability distribution for a double probability distribution.

DEPARTMENT OF COSMICAL PHYSICS (A†).

(Sir FRANK DYSON, F.R.S., in the chair.)

Friday, September 7.

Prof. E. A. MILNE, M.B.E., F.R.S.—*A popular account of the significance of absorption lines in stellar spectra* (11.0).

Dr. T. DUNHAM.—*The new Condé spectrograph of the Mount Wilson Observatory* (11.25).

Prof. O. STRUVE.—*Spectrophotometric investigations at the Yerkes Observatory* (11.50).

Prof. J. A. CARROLL.—*Accuracy of measurement in spectrophotometry* (12.15).

(1) *Instrumental.*—The effect of finite resolving power, etc., due to all causes may be represented as spreading a monochromatic source into a spectrum of intensity distribution $K(T)$, T being the 'reduced' wave-length. Thus a true distribution $I(T)$ is observed as $O(T)$ where

$$O(T) = \int_{-\infty}^{+\infty} I(T + t)K(t)dt.$$

The practical solution and use of this equation is discussed, by the aid of Fourier transformation theory.

(2) *Photographic.*—(*a*) The ability of a photographic plate to detect small changes in intensity distribution over a given region on the plate is discussed, and a quantity termed the 'Discriminating Power' of the plate is defined and shown to be a useful criterion, analogous to Resolving Power in optical theory, whereby the performance of the plate used under specified conditions may be calculated.

(*b*) Certain irregularities on a scale large compared to plate grain size are noticed and discussed in connection with variation of film thickness, measured optically by interference methods.

(*c*) An estimate of limiting accuracy under optimum conditions.

Mr. E. G. WILLIAMS.—*Spectroscopic differences between giant and dwarf early type stars* (12.40).

The present procedure for determining absolute magnitudes by the spectroscopic method is unsatisfactory for the B and O type stars. It requires considerable modification and, until this has been effected, the intensity of the interstellar line of calcium is as good a criterion of distance as any, provided this intensity is measured spectrophotometrically.

A number of typical early type stars has been selected for study. Their spectra show sharp lines and are free from such disturbing influences as axial rotation and the presence of emission lines. The stars have been

divided into high and low luminosity groups (giants and dwarfs) by the interstellar line criterion.

It is found that the intensity of both the hydrogen and helium lines is, in each subtype, greater for the dwarfs than for the giants, whereas the ionised lines of carbon, nitrogen, oxygen, magnesium, and silicon are relatively stronger in the giants. The effect for hydrogen is so marked, from type BO to A, that it could be used for absolute magnitude determination provided the exact subtype of the star was measurable. This problem of exact classification is complicated by the fact that no line studied is free from luminosity effect. Ratios of line intensity for atoms of widely different excitation potential present the most hopeful solution of the problem, but any adopted method, though based on photometric measures, should be capable of adaptation for estimates of type and luminosity by the usual visual inspection.

REPORT OF COMMITTEE ON SEISMOLOGICAL INVESTIGATIONS.

Miss E. F. BELLAMY.

JOINT SESSIONS (SECTIONS A, G) ON TECHNICAL PHYSICS.

Thursday, September 6.

(Dr. EZER GRIFFITHS, F.R.S., in the chair.)

Mr. R. S. WHIPPLE.—*A note on some of the difficulties of measuring the temperature of molten steel* (10.0).

The problem of measuring the temperature of molten steel either in the furnace or in the ladle is one of great importance to the steel manufacturer. It is, however, one of great difficulty.

The committee appointed by the Iron and Steel Institute to study the heterogeneity of steel ingots formed a sub-committee to study the temperature measurement side of the problem of ingot casting. This committee has devoted a great deal of time to the study of the problem.

The temperature of the steel in a Siemens furnace is approximately 1630° C., and the difficulty of inserting a pyrometer into the molten metal through the open door is almost insuperable. The tube protecting the thermo-elements must also be robust and non-porous, as the only elements that may be safely used at the present time for temperatures as high as 1600° C. belong to the platinum group. The committee decided that at the present time the problem could only be solved by the use of optical pyrometers, and that those of the disappearing filament type gave the most consistent results. Discrepancies in the results obtained showed that a careful study of the details of the pyrometers was necessary, and as a result exhaustive tests were made on the coloured and neutral glasses of the instruments. With the introduction of new glasses and other modifications a considerable improvement has been made in the performance of these pyrometers. The readings obtained give the apparent temperature of the steel; a correction must be applied to convert the readings to true temperatures.

The position cannot be regarded as satisfactory because there are so many factors involved in the determination of the temperature of molten steel by means of optical pyrometers, and this necessitates a considerable amount of skill when making the observations.

Mr. R. GRIFFITHS.—*Some problems in the measurement of temperature in steelworks.*

With the increasing need for closer control over the temperature in the manufacture of steel and its products the development of special forms of pyrometers has become necessary. For example, in rolling-mill practice the time required for taking an observation is a determining factor. Experiments are described which have been carried out with the object of producing a pyrometer to satisfy the requirements.

Mr. B. LLOYD-EVANS and Mr. S. S. WATTS.—*A contribution to the study of flame temperatures in a petrol engine.*

It has been recognised for many years that the calculated maximum explosion pressure in an internal combustion engine is far greater than the measured pressure. The basis of this calculation is, that both pressure and temperature rise instantaneously when the piston is in its uppermost position, termed the T.D.C. (top dead centre).

The authors have attacked the problem from the point of view of the temperatures produced, using the spectral line reversal system, developed recently by Dr. Ezer Griffiths and J. H. Awbery.

In general, the tests showed that at the particular point considered in the engine, the temperature bore little relation to the pressure, this result being almost independent of the brand of petrol used. The maximum temperature on any given temperature/crank angle curve was of the order of 2100° C. and lasted over a much longer period of time than did the maximum pressure. It was also seen that combustion as denoted by tongues of flame lasted down to at least crank angle positions of 70° to 90° after T.D.C.

As, however, the extinction of visible flame is not necessarily a criterion of the end of combustion, curves of $\frac{PV}{T}$ were plotted against crank angle. Had T been the average temperature in the cylinder at the moment considered, then $\frac{PV}{T}$ should have been constant. This was far from the case, and, in view of the turbulence in the cylinder, it can only be concluded that combustion was still proceeding.

Dr. MARGARET FISHENDEN.—*Radiation from non-luminous gases.*

As their temperature increases, radiation plays a more and more important part in the heat transfer from non-luminous gases containing water vapour or carbon dioxide. Methods of determining the radiation and convection from hot flue gases passing through a tube of internal diameter 10 in. are described.

Mr. E. G. HERBERT.—*Periodic hardness fluctuations induced in metals by mechanical, thermal and magnetic disturbance.*

A brief account is given of the experimental stages which led to the discovery of periodic fluctuations.

Typical results are given, in which periodic hardness changes were set up in pure metals, nickel, iron and gold, by mechanical, thermal and magnetic disturbances, and the fluctuations were stabilised by application of a magnetic field.

The fluctuations appear to be electromagnetic, and may be allied to other known forms of electromagnetic oscillation.

Description of a new method by which the fluctuations are autographically recorded, and correlated with changes in the elastic properties of metals.

These records indicate that the modulus of elasticity of metals is not a stable but a fluctuating property, the fluctuations being periodic in character, and capable of being induced by magnetic disturbances, including the action of stray fields.

Mr. O. A. Saunders.—*Convection in gases at high pressures.*

Theoretical considerations show how the effect of pressure on natural convection in gases may be related to that of linear size. The heat losses from large surfaces in gases at atmospheric pressure can therefore be deduced from small scale experiments at high pressures. Some experimental results are discussed.

Mr. H. de B. Knight.—*Industrial application of Thyratrons, with special reference to the control of resistance welding.*

The Thyratron is a gaseous discharge device through which current flows in the form of an arc and in which the current flow can be controlled by means of a control electrode or grid. A large range of such devices is available, with ratings varying from a fraction of an ampere to 100 amperes or more. These currents can be controlled with a negligible amount of controlling energy; and, especially in high voltage circuits, the Thyratron provides an easy means of controlling considerable power.

Particular reference is made to the application of the Thyratron in connection with resistance welding. In modern resistance welding applications some metals can only be welded satisfactorily if the welding current is of very short duration. In addition, modern production methods require very high-speed operation with precision and reproducibility. These features are practically impossible to obtain when electromagnetic relays and contactors are employed to control the welding current; but they are easily obtainable by the use of the Thyratron.

A single impulse Thyratron-controlled spot-welder for pedal operation will be described and demonstrated.

Mr. L. J. Davies and Mr. J. H. Mitchell.—*Resonance radiations in electric discharge lamps.*

This paper aims at showing the importance of the phenomena of resonance radiations in connection with the nature of the light output from various types of electric discharge lamps.

The resonance and general emission spectra, together with other physical properties on various elements, are discussed with a view to their possible utilisation in discharge lamps; in particular resonance phenomena for the cases of mercury and sodium are dealt with in detail.

Mr. H. R. Ruff.—*The commercial production and utilisation of ultra-violet radiation.*

The large scale utilisation of ultra-violet radiation for such purposes as artificial lighting, manufacture of special chemicals and sterilisation of food-stuffs, utensils, and the water of swimming baths is assuming a rapidly increasing importance.

This paper describes methods for the industrial production of ultra-violet radiation and some typical applications, and discusses also methods of rating such sources to enable the user to evaluate their worth for any particular purpose.

Mr. L. J. Davies and Mr. R. Maxted.—*Some aspects of modern road illumination.*

This paper deals with the application of light for the provision, on highways at night time, of a visibility sufficient for the requirements of modern traffic conditions.

The optics connected with the process of seeing and distinguishing objects on artificially illuminated roadways are discussed. Light can be applied from moving vehicles or from stationary lighting points, and, for economical and other reasons, a mixture of the two methods, adjusted according to the traffic burden of the road, is a reasonable solution.

Some possible lines of development are suggested.

Monday, September 10.

(Sir James Henderson in the chair.)

Dr. Ezer Griffiths, F.R.S.—*Research on heat transmission and its relation to industry.*

In the design of structures involving the conservation of heat or cold, data as to thermal conductivity play an important part, and this is illustrated by consideration of typical cases which include buildings, furnaces and ships.

Measurements have been made on a variety of heat-insulating materials, and data are given for pumice concrete, aerated concrete, aluminium-faced asbestos paper, compressed fibre boards, etc.

In the second part of the paper consideration is given to the question of the basic laws of the transfer of heat between gases and solids, and to the application of the data obtained to the design of batteries for the heating or cooling of air.

When heated pipes are arranged in bank formation the second layer loses in an air stream more heat than the first, whether in square or in diagonal formation. In square formation the third layer loses the same as the second, whilst in diagonal formation there is an increased loss in the third layer over the second. After the third the coefficient is constant.

The effect of fins fitted to the pipe in increasing the heat transfer is considered and data given.

Dr. J. Small.—*Thermal conditions round a hot circular cylinder in a stream of fluid.*

An experimental study of the variation in the rate of heat transmission from point to point round the surface of a heated cylinder in an air stream is made by means of an indicator built into the surface. When the cylinder is heated only in the region of the indicator a minimum value is recorded at the upstream generator as well as at generators which are about 90° of angle from the front. This minimum at the front is not obtained in experiments on a uniformly heated cylinder. The results are analysed and compared with those of other experimenters.

The equation for the temperature distribution in a perfect fluid flowing past a heated body is $\nabla_{\alpha\beta}^2 \theta = \frac{c V}{K} \cdot \frac{d\theta}{d\beta}$. The usual assumption that $\frac{d^2\theta}{d\beta^2}$ is negligible as compared with $\frac{d^2\theta}{d\alpha^2}$ implies an indefinite rate of heat flow at the upstream generator of the cylinder. A solution which does not involve this assumption is obtained by a method of successive approximations based on an application of Taylor's Theorem. Constant temperature lines are drawn in the α, β field.

Measurements of temperature of the air by means of a platinum resistance wire stretched parallel to a generator of a metal cylinder (heated internally by steam) and placed at different distances from its surface, show the characteristic spreading of the isotherms towards the sides of the stream beyond an angle of 90° from the upstream generator.

Careful experiments in which the average rate of heat transmission from the surface is measured yield values higher than those obtained by most other observers, but closely agree with the recent results of Griffiths and Awbery.

Mr. A. H. Douglas.—*Modern building materials with a view to thermal insulation of buildings.*

During the last quarter-century, economic pressure, coupled with the increasing use of steel and reinforced concrete frameworks, has led to the cutting down of thicknesses of traditional building materials, such as brick, stone, slate and timber, in the building of walls, floors and roofs, resulting in an undesirable lowering of their overall heat and sound insulating qualities.

Considerations of cost preclude any return to traditional methods, so that a solution must be found, (*a*) by new methods of design, such as various forms of cavity wall, based on more accurate knowledge of thermal phenomena ; (*b*) by the introduction of highly insulating non-structural materials for use in conjunction with the traditional structural elements ; (*c*) by the development of new forms of structural unit of substantially greater insulation value than the existing range, for use either alone or in conjunction with the latter. The above methods may of course be used either alone or in suitable combination.

Much valuable work has been done during the past decade in regard to (*b*), for special uses such as refrigeration chambers, but cost has hitherto prevented its application to the wider field of general building practice.

Increasing attention has been paid lately to (*c*) in an effort to avoid extra cost by a wider combination of functions in the material used. Such materials, in association with suitable kinds of tensile reinforcement, are found to approximate in many ways to the traditional timber element, without sharing its disadvantages in regard to fire, movement and rot. In fact they might aptly be described as forms of ' mineral timber,' and interesting results have already been secured by following out this line of thought.

Mr. A. Lindsay Forster.—*Glass silk as an insulator for heat and sound.*

Mr. F. C. Johansen.—*Problems of refrigerated railway transport.*

The relatively short duration of the journeys affects in several ways the economics of refrigerated railway transport in Great Britain. For example, the cold absorbed by the vehicle on loading and lost on discharging are an important proportion of the total refrigeration, and hence low thermal

capacity, as well as low conductivity, is a desirable quality of insulated vehicles. The low density of appropriate insulators is also advantageous from the standpoint of haulage costs, but adequate endurance and retention of thermal properties affects the choice of material. Other good features aimed at in the vehicles are air-tightness, size and dimensions to accommodate full loads, and ease of cleansing. With mechanically refrigerated vans, thermal capacity is less important since pre-cooling is easy. But mechanical refrigeration involves a large unit, and is economical only for long-distance regular traffic. For small vehicles, in random service, refrigeration by solid CO_2 is generally very convenient, but immersion in the sublimed gas affects certain food products detrimentally. If, on this account, the gas is led into the insulation space, the choice of a suitable insulating material is affected.

Mr. A. F. Dufton.—*The equivalent temperature of a room and its measurement.*

The traditional method of determining the temperature of a room is by means of a thermometer, and until recently neither the cooling effect of draughts nor the influence of the temperature of the walls has been fully appreciated. Although in terms of our sensations we say, ' It is colder now that the sun has gone in,' or ' Come round the corner ; it will be warmer out of the wind,' there has been no scale of temperature to enable us to express how much colder or how much warmer.

The temperature of an environment with air and walls at different degrees is not easily specified. From the point of view of human comfort it is the rate at which heat is lost by the body which seems to be important. The *equivalent temperature* of an environment has been defined as that temperature of a uniform enclosure in which, in still air, a sizable black body at 75° F. would lose heat at the same rate as in the environment. This scale of temperature does not extend above 75° F. At high temperatures changes in the humidity cease to be immaterial so far as heat losses from the body are concerned ; the environment, moreover, is warmer than necessary for comfort.

In 1929 an instrument was constructed for recording equivalent temperature. This instrument, which is called a eupatheoscope, was designed for use in researches on heating and ventilation. It is somewhat cumbrous and the need has now been felt for a simpler instrument for general use. It has been found that the equivalent temperature of an environment can be computed from the rates of cooling of two large-bulbed thermometers heated to 75° F., one of the thermometers having a silvered bulb.

To simplify the computation a special face has been fitted to an ordinary stop-watch, which enables the equivalent temperature to be evaluated from the cooling times by the mere addition of two numbers.

Mr. T. C. Angus.—*Physical tests of the properties of clothing based on physiological standards.*

In a research intended to provide a simple method for determining the heat-retaining properties of clothing materials, it became apparent that the value of results may be small if the physical test conditions depart too far from the physiological state and environment of the clothed human body in cool air.

The insulating properties of a cloth are measured by determining the amount by which a covering of the cloth will prevent the cooling of the

surface of a partial insulator covering a heated body. In other words, the cloth sample is placed over an artificial ' skin ' covering a warm artificial ' human body ' in the form of a heated water container, and the temperature variations at points underneath the clothing and on the surface of this artificial ' skin ' are measured.

It is found that the ' skin ' temperature rises when clothing is placed over it, the rise in temperature being measured by differential thermopiles.

From this we calculate variations of heat retention as percentages of complete insulation, having independently developed the method of calculation previously used by Barker.

The advantage of this experimental method is that the effects due to variation in the tension by which the samples are stretched can be examined, also variations due to changes in wind velocity.

Mr. G. P. Crowden.—*The use of bright metallic surfaces for increasing human comfort in the tropics.*

A comfortable, clothed, sedentary individual produces some 400 B.Th.U. per hour by reason of the chemical changes associated with living processes, circulation, respiration and glandular activity. In still air at 60° F. and 50 per cent. humidity, roughly 45 per cent. of this heat is lost by radiation. At 80° F. loss by radiation is approximately halved, while under tropical conditions a gain of heat by radiation from the surroundings necessitates increased loss by evaporation of sweat to keep the body temperature normal.

Human comfort in the tropics can be increased by any means of reducing heat gain by radiation. The well-known physical properties of high reflectivity and low emissivity for radiant heat possessed by bright metallic surfaces can be made use of for this purpose. It has been shown that if an air space of 1 in. is divided medially by a layer of bright metallic airproof material, known as reinforced aluminium foil, the passage of heat across the space is as effectively hindered as if 1 in. of cork or 13 in. of brick were used. This insulation has been used in tropical helmets, galvanised iron hutments and tents, and laboratory and field tests have proved its value for increasing human comfort.

Mr. S. G. Barker.—*The interpretation of physical data regarding textiles in terms of bodily comfort.*

The analysis of the figures obtained for a large variety of fabrics made from different textile materials indicates that fabric structure and thickness is of paramount importance.

The paper is extended to the question of hygienic coverings during sleeping and the manufacture of beds and bedding.

Physical data are quoted in support of the arguments put forward, and definite inferences are drawn regarding ideal conditions from the physicist's point of view for realising bodily comfort.

Dr. M. C. Marsh.—*The interchange of heat as affecting clothing material.*

The paper is a review of the heat interchange processes which occur when fabrics are used as thermal insulators under the conditions normally obtaining in clothing. Fabrics in general have a rough surface owing to the method of their construction, and the effect of this on heat interchange is first considered and shown to be of primary importance.

When a large number of results is available, the general effects of air permeability and the ability to transmit radiation can be determined. In

this way it is possible to show that in the case of the less permeable fabrics there is an interchange of heat between the material of the fabric and the air stream which flows through the interstices.

Mr. A. Bailey and Mr. W. F. Cope.—*Heat transmission in pipes of square and rectangular section.*

The paper describes experiments carried out at the National Physical Laboratory. The conclusion is drawn that such pipes behave in a similar manner to circular pipes of the same hydraulic diameter.

SECTION B.—CHEMISTRY.

Thursday, September 6.

Presidential Address by Prof. T. M. Lowry, C.B.E., F.R.S., on *Physical methods in chemistry* (10.0). (See p. 29.)

Dr. R. G. J. Fraser.—*Applications of molecular rays to chemical problems* (11.15).

The Method of Molecular Rays.—Modern vacuum technique allows the production of beams of neutral molecules, moving with thermal velocities *in vacuo*. Hence molecular properties can be studied directly, without the necessity for statistical arguments.

Applications of the method more immediately touching chemical problems are:

Dissociation.—If a non-magnetic diatomic molecule dissociates into magnetic atoms, and a mixed molecular-atomic beam is sent through an inhomogeneous magnetic field, the atoms suffer deflection, the molecules are unaffected. Thus the atoms and molecules can be physically separated, and their relative numbers determined.

Molecular cross-sections.—The weakening of a beam of molecules on traversing a vapour determines their mean free path and collision area Q. Methods have been devised which permit extrapolation to beams of negligible width. Hence Q values are obtained which are independent of the geometry of the apparatus.

Dipole moments.—The deviation of a beam in an inhomogeneous electric field determines the molecular dipole moment μ. The dipole moment is measured outright, at a single temperature. Hence a possible dependence of μ on temperature is readily established.

Free radicals.—A molecular ray is collision free; hence the primary products of chemical reactions can be isolated in the beam and examined by special methods.

Dr. H. de Laszlo.—*Determination of molecular structure by electron-diffraction* (11.35).

The technique of obtaining photographic records of the scattering of fast electron beams by vapours and gases has been simplified and perfected in the following way.

(*a*) The interference pattern of the vapour of any substance that will vaporise *in vacuo* up to 1000° C. without decomposition can be photographed by means of a small oven, equipped with an original type of

vaporising nozzle. This permits the investigation of a great variety of molecules which could not have been measured by the older methods.

(*b*) This nozzle, either in conjunction with the oven or by itself when using substances with a high vapour pressure at room temperature, coupled with the use of Ilford X-ray emulsions, enables one to record many more interference maxima than had previously been possible.

(*c*) These new high order maxima are particularly sensitive to changes in chemical structure. Hence we can now make an accurate determination of interatomic distances and the molecular architecture of many substances whose spatial configuration has hitherto been unknown.

(*d*) The high $(\sin \theta/2)/\lambda$ values of the maxima that are now available permit the use of a simplified method of calculating the theoretical scattering curves, with which the experimental results are compared, with a consequent saving in time.

These technical improvements have turned the electron-diffraction method into a quick, reliable, and accurate tool for the determination of chemical structure in the vapour phase. It should now be possible to clear up most of those debatable points in chemistry where a knowledge of the spatial structure is essential.

Mr. S. F. Boys.—*The origin of optical rotatory power* (12.0).

Measurements on the refractive indices, etc., of pure compounds have led to the view that the atoms in a molecule are polarised under the action of the electric field of a light wave. The polarisation constants of particular elements are well known, and are tabulated under the name of refractivities.

If an asymmetric molecule is examined and the atoms are assumed to have the usual polarisibilities, it is possible to calculate the complete optical properties of the liquid composed of such molecules. If the liquid only contains one of the two enantiomorphs, the calculation shows that, in general, the liquid must rotate the plane of polarisation of a transmitted light wave.

The predicted values of the optical rotatory powers of certain simple compounds, e.g. amyl alcohol, have been found, and these agree with the experimental values.

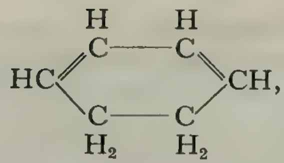
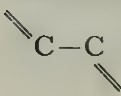
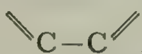
The calculation makes it possible to state the conditions which determine whether a given simple molecule is dextrorotatory or lævorotatory. This relation can be used in the reverse sense and it is possible to determine the absolute configuration of some optically active compounds.

Mr. E. Eastwood and Dr. C. P. Snow.—*Optical properties of conjugated compounds : (a) The absorption spectrum of acrolein* (12.40).

Unlike the saturated aliphatic aldehydes, which give very complex band spectra, acrolein, $CH_2=CH-CH=O$, gives a band spectrum in which the rotational structure is as sharp as in the diatomic gases. This structure, however, presents the unique anomaly that the moment of inertia deduced for the ground state of the molecule, instead of being constant throughout, is different for each vibrational band.

Dr. C. B. Allsopp.—*Optical properties of conjugated compounds : (b) The origin of optical exaltation in conjugated hydrocarbons* (12.45).

Contrary to the prediction of Brühl, but in confirmation of observations by Willstätter, the conjugation of two double bonds in 1 : 3-cyclo-

hexadiene,  produces no optical exaltation in the visible spectrum, although the molecular refraction M_D of 2 : 4-*hexadiene*, $CH_3-CH=CH-CH=CH-CH_3$, is 1·65 units higher than that observed in *diallyl*, $CH_2=CH-CH_2-CH_2-CH=CH_2$, where the two double bonds are isolated from one another by three single bonds. Exaltation is observed, however, at wave-lengths in the vicinity of a strong ultra-violet absorption band which is characteristic of the conjugated system. The magnitude of the optical exaltation will depend on the position and intensity of this absorption band, which may be influenced by many factors. It is suggested that one of these factors may be the relative orientation of the conjugated double bonds, which can take up a *parallel* configuration,  , in *open-chain* compounds, but are held in an inclined configuration, , in *ring* compounds.

AFTERNOON.

Visit to Stoneywood Paper Works of Messrs. A. Pirie & Sons, Ltd.

Friday, September 7.

DISCUSSION on *Ascorbic acid (vitamin C)* (10.0) :—

Prof. A. HARDEN, F.R.S.—*History of vitamin C.*

It was recognised as early as 1734 that scurvy was due to the lack of fresh vegetable food and could be cured by the supply of this. In 1907 scurvy was ' brought into the laboratory ' by Holst and Frölich, who, using the guinea-pig, made a rough and mainly qualitative survey of the antiscorbutic potency of foodstuffs and studied the effects of heat and preservation on this property. Fürst, in the same laboratory, also found that in leguminous seeds antiscorbutic potency arose during germination. Strictly quantitative observations soon followed, first in England and then more generally, and it was found that the antiscorbutic vitamin, as it was now called, was very unequally distributed among vegetables and fruits, etc. Studying the physical and chemical properties of the vitamin, Zilva, of the Lister Institute (1924 and onwards), succeeded in concentrating it about 200 times and found that the preparations always had strong reducing properties. Removal of the reducing power by titration with indophenol did not inactivate the preparation, but this soon became inactive on keeping. This behaviour was interpreted as being due to the presence of a reducing principle which exerted a protective influence on the vitamin. In 1932 Tillmans and Hirsch confirmed these facts, but showed that the oxidation by indophenol was reversible and that the facts were consistent with the conception that the vitamin itself had reducing properties. They further suggested that it might be identical with the strongly reducing hexuronic acid found in the adrenals and in many vegetable juices by Szent-Györgyi (1928). The discovery by the latter (1932) that this acid, henceforward to be known as

ascorbic acid, had powerful antiscorbutic properties soon led to a general agreement that ascorbic acid was vitamin C. The easy preparation of this substance in quantity from paprica provided material for the determination of its constitution at the University of Birmingham (March 1933), and this was rapidly followed by the synthesis of the acid (August 1933) both in Birmingham and in Switzerland and the demonstration of the full antiscorbutic potency of the synthetic substance.

Prof. A. Szent-Györgyi.—*Isolation of ascorbic acid and its identity with vitamin C : physiological properties and clinical uses.*

There seems to be no cell life in higher organisms without ascorbic acid. The exact biological rôle played by this substance is, however, unknown. The most characteristic chemical feature of ascorbic acid is its high reducing power and the reversible nature of its oxidation. There is little doubt that the biological function of this substance is connected with this reaction.

In spite of its simple chemical structure *l*-ascorbic acid is a highly specific substance. Closely related substances with the same reducing power (for example, its stereoisomers) are unable to replace it in biological reactions.

Not all animals are dependent on their food for ascorbic acid. All animals of our climate are capable of synthesising it. The inability of man to produce it pleads for his tropical origin.

Ascorbic acid having become available for medicine only very recently, its medical applications are not yet sufficiently settled. The first clinical medical experiments, however, have revealed some very striking and unexpected effects. Ascorbic acid seems to be able to cure in a very striking manner several diseases against which medicine was helpless, such as *purpura hæmorrhagica*, *Werlhoff's disease*, certain forms of *hæmorrhagica nephritis* and *hæmophilia*, *pyorrhœa*, etc. This is the more striking since these pathological conditions have not been thought to be connected with lack of vitamin. These curative effects suggest that humanity is suffering much more gravely from a lack of vitamin C than has hitherto been supposed.

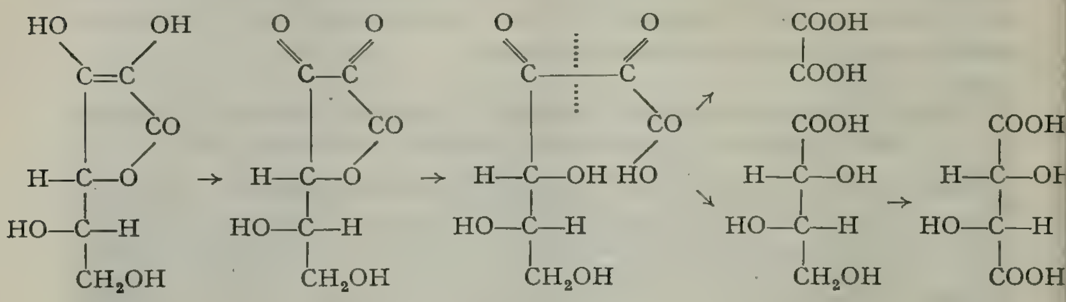
Also the major part of pathologic pigmentations can be made to disappear by ascorbic acid. So, for instance, patients with *Addison's disease* can be bleached out again by the use of this substance.

Summarising, we thus see that, in the short space of time of two years, the mysterious vitamin C has been identified, its chemical structure determined, its synthesis effected. It has also been made available for industry and medicine, and its medical value ascertained. It is pleasant to note that this unparalleled advance is due entirely to the closest and friendliest international collaboration.

Dr. E. L. Hirst, F.R.S.—*The chemical properties and structure of ascorbic acid.*

Insight into the chemical structure of ascorbic acid originated from a study of its oxidation products. The first (reversible) stage terminates with the formation of an αβ-diketo-acid (III), which on more drastic oxidation gives rise to oxalic acid and *l*-threonic acid (IV), the constitution of the latter being proved by its transformation into *d*-tartaric acid (V). The stereochemical relationships and the main features of the structure of ascorbic acid were thus elucidated. Further advance became possible with the discovery that the first oxidation product at the moment of its formation is not the acid (III) but a lactone (II) which subsequently hydrolyses to the free acid. It followed from this observation that ascorbic was not

a carboxylic acid but owed its acidic character to the presence of an enolic hydroxyl group. At this stage of the investigation (March 1933) sufficient chemical and crystallographic evidence had accumulated to support the proposal of the structural formula (I).



(I) (II) (III) (IV) (V)

It remained only to decide whether a γ-(1 : 4) or a δ-(1 : 5) lactone ring was present, and in April 1933 a clear decision in favour of the γ-lactone structure was obtained from investigations on the tetramethyl ether of ascorbic acid. This substance gives on degradative oxidation a dimethyl *l*-threonic acid which has the free hydroxyl group in the α-position. The presence of a γ-lactone in ascorbic acid (I) was therefore definitely established. Confirmation of these views was then provided by the synthesis of ascorbic acid from *l*-xylosone.

The chemical and physical properties of ascorbic acid are considered in relation to its molecular structure.

Mr. E. Gordon Cox.—*Crystallographic contributions to the study of ascorbic acid.*

The unusual chemical properties of ascorbic acid are such that at an early stage in the study of its constitution it was possible to suggest two or three spatial formulæ, any one of which, however, could only be finally established or eliminated by much time-consuming study. Any additional experimental method which could be used to discriminate between the possibilities was therefore of great value. Whilst it is usually very difficult to prove the correctness of a given structure by the use of X-rays, it is often relatively easy to eliminate suggested alternatives. This was found to be so in the present case. Of the constitutional formulæ proposed only one was found to fit the observed optical and X-ray data. In a relatively short time this formula was established by chemical methods as correct. During this latter stage of the work, X-ray methods were again found to be of use in determining molecular weights and identifying degradation products, especially in cases where the yield was very small, or where melting point was uncertain.

The next step, that of synthesis, was also assisted by crystallographic methods. In the early stages work was naturally on a small scale, with correspondingly small yields ; X-rays and microscopic examination were used to identify products and thus to prevent waste of time and material on syntheses under unfavourable conditions.

More detailed crystallographic work on ascorbic acid and related compounds has been carried out in order to determine as far as possible some of the finer details of the structure.

Dr. T. Reichstein.—*Investigations in the field of ascorbic acid and related substances.*

The first effort of Reichstein, Grüssner and Oppenauer in the field of ascorbic acid is not the only example of synthetic studies which, though based on incorrect suppositions, have turned out successfully. At the time when we began our work the incorrect furoid formula of Micheel and Kraft had just appeared. Being myself a furan specialist, this formula stimulated my curiosity, and work was commenced on the following lines :

(1) Attempts were made to find models containing an endiol group, and the probable influence of ring structure was studied.

(2) Efforts were made to synthesise substances analogous to ascorbic acid (3-keto-sugar acids) and also ascorbic acid itself.

Two methods were developed : (*a*) I attempted a rearrangement of 2-keto-acids (osonic acids), while (*b*) my collaborator, R. Oppenauer, proposed the treatment of osones with hydrocyanic acid. Positive results were first obtained from the latter. The former was the more difficult, since the appropriate 2-keto-acid was not available, and the necessary conditions to induce it to enolise were not quite those expected.

(i) *Osone-HCN Method.*—This was developed independently in Birmingham and Zürich with successful results.

(ii) *Transformation of 2-keto-acid.*—The results of H. Ohle and of Maurer and Schiedt on the enolisation of 2-keto-*d*-gluconic acid appeared while we were engaged on the preparation of 2-keto-*l*-gulonic acid (*l*-gulosonic acid), the correct formula of ascorbic acid having meanwhile been established by the Birmingham investigators. Details of these results are given.

(3) Reductic acid will be described as a simple analogue of ascorbic acid, and the γ-lactone formula will be discussed.

(4) Attempts have been made to correlate configuration and antiscorbutic properties.

Prof. W. N. Haworth, F.R.S.—*Synthesis of ascorbic acid and its analogues.*

The experimental methods which have been applied at Birmingham for the synthesis of *d*- and *l*-ascorbic acid may be summarised as follows :

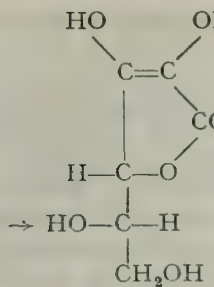
(1) Addition of hydrogen cyanide (reagents potassium cyanide and calcium chloride) to *l*-xylosone. Yield, 70 per cent. (The method of direct addition of liquid hydrogen cyanide was published independently and almost simultaneously by Dr. Reichstein.)

(2) Oxidation of gulosone direct to 2-keto-gulonic acid, followed by isomerisation by the method of Ohle (*Z. Angew. Chem.*, 1933, **46**, 399) and of Maurer (*Ber.*, 1933, **66**, 1054).

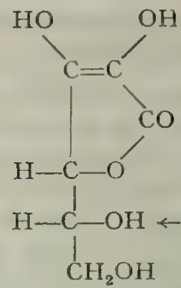
(3) Direct oxidation of sorbose to 2-keto-gulonic acid followed by isomerisation.

In addition, the same methods have led to the synthesis of seven isomers or analogues of the natural vitamin. The fact that arabinosone by the potassium cyanide method gave the same product as that of Ohle and Maurer (isomerisation of a 2-keto-gluconic acid) showed that either a 2- or a 3-keto-hexonic acid could isomerise to the same ascorbic acid type.

The synthetic *l*-ascorbic acid (I) has the same physiological activity as the natural product (Haworth, Hirst and Zilva). Of the isomers and analogues obtained so far only the *d*-arabo-ascorbic acid (II) shows activity which is in the least comparable.



(I)



(II)

It will be seen that the above configurations (projection formulæ) are identical with respect to the stereochemical arrangement of groups attached to the ring and differ only by the reversal of one OH-group in the side chain. If this principle holds we should expect also the following, which are in course of preparation, to show some physiological activity: *l*-gulo-ascorbic acid and also the *l*-galacto-, *d*-allo- and *d*-erythro-ascorbic acids.

Afternoon.

Visit to the Laboratories of the Fishery Board for Scotland and of the Department of Scientific and Industrial Research, Torry.

Monday, September 10.

Joint Discussion with Section A (Mathematical and Physical Sciences) on *The physical and chemical properties of heavy hydrogen* (10.0):—

Prof. E. K. Rideal, M.B.E., F.R.S.—*Introduction.*

Dr. A. Farkas.—*Some properties of heavy hydrogen.*

A micromethod has been developed based on the different thermal conductivity of light and heavy hydrogen. One can estimate by this method the relative amount of the molecular species H_2, HD and D_2 and of their ortho- and para-modifications in $2–3 \cdot 10^{-3}$ c.cm. of gas (N.T.P.). The reaction between H_2 and D_2 proceeds in the gas phase above 500–600° C. according to both an atomic and a molecular mechanism, but can be catalysed at much lower temperatures. The equilibrium constant of this reaction is about 4 and nearly independent of temperature. It is shown that when H_2 and D_2 diffuse through a fine nozzle a separation occurs on account of their different molecular velocities. On the other hand, the different rate of diffusion through palladium is due to a different heat of activation for this process caused by the difference in the zero point energies of light and heavy hydrogen. In collaboration with Dr. Harteck it was shown that, similarly to the case of ordinary hydrogen, the ortho-para-conversion occurs also with D_2. From kinetic and equilibrium measurements we can deduce the following information concerning the D-nucleus: (*a*) The Bose-Einstein statistics are applicable; (*b*) the nuclear spin $= 2/2$; (*c*) the magnetic momentum $= 0{\cdot}5$ nuclear magneton.

Mr. H. W. Melville.—*Heavy hydrogen: its bearing on problems in chemical kinetics in gaseous systems.*

In the investigation of the kinetic behaviour of heavy hydrogen compared with that of light hydrogen, the types of reaction may be divided into three

classes: (1) Reactions of the free atoms; (2) reactions of the molecules; (3) catalytic reactions in which a compound of hydrogen is the intermediate product effecting hydrogenation.

In each of these cases, there are three factors which may cause the velocity of reaction of hydrogen to be greater than diplogen: (*a*) a collision factor, the maximum ratio being $\sqrt{2}:1$; (*b*) the contribution of zero point energy to the energy of activation of the reaction; and (*c*) the quantum mechanical leakage of the atoms or molecules through potential barriers, where these exist.

As examples of the first class there are the mercury photosensitised hydrogenations of oxygen, nitrous oxide, ethylene and carbon monoxide, and the reduction of copper oxide. In the second class there are the hydrogen-chlorine and hydrogen-bromine reactions. In the third class, the hydrogenation of oxygen, nitrous oxide, and ethylene on a nickel surface, the diffusion of hydrogen through palladium, the reduction of copper oxide and the establishment of the equilibrium $H_2 + D_2 \rightleftharpoons 2HD$.

The separation of the two isotopes does not occur in every one of these reactions, but in those cases where it is effected, the difference in velocities can, in general, be explained by the collision and zero point energy factors.

Mr. G. B. B. M. Sutherland.—*The importance of heavy hydrogen in molecular physics.*

One of the outstanding problems in present-day molecular physics is that of determining the exact nature of the force field which exists between the various atoms of a polyatomic molecule. It may be approached in two ways. From our knowledge of the electronic structure of the separate atoms, we may, by using the methods of quantum mechanics, attempt to compute the interatomic force field. The mathematical difficulties are, however, so great that this method is necessarily limited to a very few of the simplest molecules. Alternatively we may relate the constants determining the force field to the fundamental vibration frequencies of the molecule, as determined from infra-red and Raman spectra. It happens, however, that in general there are more arbitrary constants in the potential function than there are frequencies by which to determine them, so that one has to make some special assumption regarding the nature of the force field in order to reduce the number of arbitrary constants to be less than, or equal to, the number of fundamental frequencies. The importance of the new isotope lies in the fact that (for molecules containing hydrogen) we may replace a hydrogen atom by a diplogen one and so obtain a new set of frequencies which are still however related to the same set of force constants. It is therefore possible to obtain the force constants in the most general type of potential function without making those specific and rather doubtful assumptions which have hitherto been necessary.

The structure of water and of ice has long been a matter of controversy in molecular physics. The advent of heavy water with its characteristically different physical properties should prove a touchstone whereby any theory of the structure of ordinary water and ice may stand or fall, since any complete theory of the structure of ordinary should enable one to predict the properties of the heavy water.

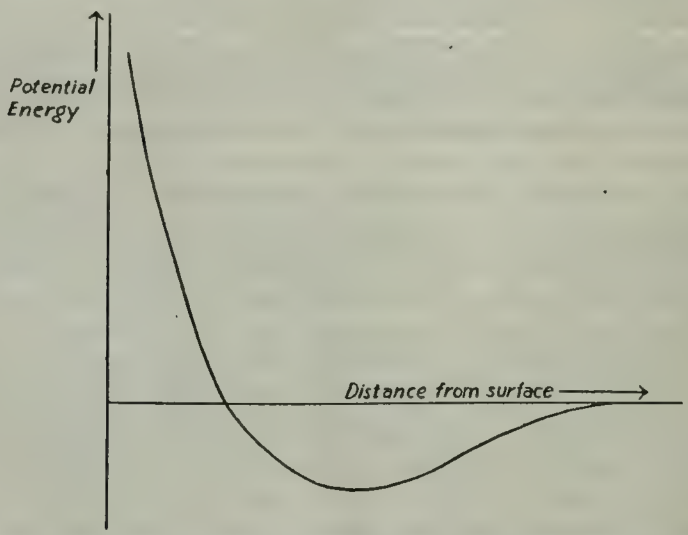
Dr. L. Farkas.—*Some chemical reactions of heavy hydrogen.*

The interaction $D_2 + H_2O$ takes place in the gas phase above 500° C., the mechanism being in principle similar to that of the $H_2 + D_2$ reaction. From catalytic experiments we have found that the equilibrium constant

of the reaction $H_2O + HD = HOD + H_2$ is $3 \cdot 8$ at $20°$ and $1 \cdot 8$ at $100°$ C. It is pointed out that this equilibrium reaction may play an important rôle in the electrolytic separation of the hydrogen isotopes. The same applies also to the separation observed in dissolving metals in water or in acids in presence of heavy water. In the case of the photochemical hydrogen-chlorine reaction it is shown that the heavy hydrogen reacts slower than the light, since its activation energy for the first step of this chain reaction is larger owing to its smaller zero-point energy. In collaboration with Prof. Rideal we have found that in the catalytic interaction of heavy hydrogen and ethylene two reactions take place simultaneously but independently: the addition of hydrogen and the exchange of hydrogen. With Mr. Yudkin we have investigated the enzymatic decomposition of sodium formate in presence of heavy water by *B. coli*. The hydrogen evolved is in equilibrium with the water, and also the interaction $H_2O + HD = HOD + H_2$ is readily catalysed by the bacteria.

Mr. C. Strachan.—*Adsorption of gaseous isotopes.*

The possible energy states of an atom or molecule adsorbed on the surface of a solid have been considered by the methods of wave mechanics. The solid is treated as in the theory of specific heats developed by Born, Debye and others. The adatom is supposed held by forces giving a potential energy which varies somewhat as shown with distance from the surface.



Under the influence of the heat motion of the solid the adatom can take up states of different energy in this potential energy trough and can perhaps evaporate from the surface.

A knowledge of heat of adsorption, difference of zero-point energy for isotopes, and results from adsorption isothermals can give quantitative information about the parameters involved in the description of the above potential energy curve. The analysis then allows the evaluation of: (1) Average time intervals between transitions of adatoms from 'bound' states to states when surface migration is possible, (2) probability of evaporation, and (3) length of life of adatom in 'migratory' state, together with their dependence on temperature and the differences of behaviour of isotopes. In particular, results are obtained for hydrogen (H and D) adsorbed on

copper and palladium, and conclusions are drawn about the mechanism of evaporation of hydrogen from a state of adsorption in atomic form.

More recently a discussion of dissociation and recombination of molecules at a crystal surface is being developed.

AFTERNOON.

Visit to Macaulay Institute for Soil Research, Craigiebuckler.

Tuesday, September 11.

JOINT DISCUSSION with Section M (Agriculture) on *The chemistry of milk* (*Section B room*, 10.0) :—

Prof. H. D. KAY.—*Introduction.*

Dr. J. F. TOCHER.—(a) *The composition of milk and the present regulations* (10.15).

The proportions of the constituents of milk are known to vary widely from sample to sample even in the case of bulked milk. In 1925 the author described the form of variation for each constituent. In the case of fat and solids-not-fat percentages, it was shown that many cases occurred where the values fell below the prescribed presumptive limits under the regulations. These regulations were made at a time when no accurate knowledge existed of the observed minimum limits in the case of herds. Legal enactments, however, should follow scientific knowledge, not precede it. One of the difficulties encountered is a method of detecting 'watering.' Many cases have occurred where *genuine* milk has been held to be watered. An equation has been found from which it is possible to detect watering within certain limits, which can be used in conjunction with the observed freezing point. The results will be published at an early date together with the freezing point results obtained from the same samples.

(b) *Variations in the freezing point of milk.*

It has been found by various workers that there is very little variation in the freezing point of milk, even if samples are taken from individual cows. It is the least variable of all the physical characters, the coefficient of variation being approximately 1·5 as against 4·5 for refractive index and 5 for specific gravity. On account of its low variability the freezing point of milk has been frequently used as a criterion of 'watering.' No general agreement has, however, been reached as to the actual range of values in genuine samples. Different results have been obtained from the same sample, due chiefly to the practice of placing alcohol between the freezing tube and the ether flask. In one case the alcohol is removed after cooling, while in the other it is retained. Much more constant and accurate results are obtained by removing the alcohol, which is useful only to promote rapid cooling. The author, in 1925, showed that, in the absence of alcohol, the values varied from $-0{\cdot}50°$ C. to $-0{\cdot}56°$ C. in fresh samples from individual cows. Certain workers hold that if the freezing point of a sample is greater than $-0{\cdot}52°$ C., water has been added. Before, however, one can estimate whether watering has taken place one must know the number of cows whose milk has been bulked. Variation in bulked samples is naturally greater than in samples from one cow. Values of $-0{\cdot}50°$ C. have been obtained

from the bulked fresh milk of a herd. On that account it would be difficult to say whether milk has been watered if values in the neighbourhood of $-0 \cdot 50°$ C. were obtained. The author has found the form of the freezing point curve for moderately concentrated aqueous solutions of non-electrolytes. The results obtained from the use of this curve have been applied in order to get the best approximation to the true freezing point of milk.

Dr. W. L. Davies.—*Chemical composition of abnormal milk* (10.40).

Milk may be defined as abnormal when its contents of fat, casein and/or lactose fall outside certain expected ranges or when it shows abnormality of behaviour towards rennin or heat, or abnormal buffer value.

The following table [1] gives the expected levels of composition of normal cow's milk and the composition of milk which must be considered abnormal, for comparison :—

Values in percentage of weight of the fresh milk.

	Normal Milk.		*Abnormal Milk.*
	Range.	Average.	
Fat, per cent. . .	2·8–5·5	3·6	Usually low.
Lactose, per cent. .	4·0–5·2	4·9	$<4 \cdot 2$
Chlorine (Cl), per cent.	0·045–0·150	0·095	$>0 \cdot 150$
Total nitrogen . .	0·46–0·54	0·50	Variable.
Percentage of total nitrogen.			
Protein nitrogen .	92–96	94	High in retained milk, otherwise low (85–91).
Casein ,, .	74–81	76	Less than 74.
Albumin ,, .	11–13	12	Both or either, high and variable.
Globulin ,, .	5–7	6	
Non-protein nitrogen	5–7	6	Low in retained milk, otherwise high (9–15).

On the assumption that abnormal milk = true milk fraction (containing casein N = 76 per cent. of total nitrogen) + diluting fraction, the nitrogen distribution and chlorine content of the diluting fraction has been calculated.[2] The fraction closely approaches blood or lymph serum or œdema fluid in composition ; this points to abnormality as being due to inefficiency in the secretory process in the elaboration of casein from the nitrogenous compounds of the blood and in secreting lactose.

Abnormality in buffer value in the acid range, in the balance of acidic and basic constituents, in the distribution of ionic and non-ionic metallic radicles (Ca), in the amounts of the various forms of casein present and in the amount of heat-coagulable protein, is reflected by abnormality in rennet action, in ' curd tension ' and in heat stability at temperatures above 100° C.

Discussion (11.0).

Dr. K. Linderstrøm-Lang.—*Some chemical and physical properties of casein* (11.20).

Casein (caseinogen), the phosphor protein in milk, is a mixture of two or more substances. By treatment with acid alcohol it may be divided into

[1] Davies, *J. Dairy Res.*, 1933, **4**, 142. [2] *Ibid.*, 1933, **4**, 273.

several fractions that differ in chemical composition, especially in their content of phosphorus. Mixing the fractions in their original proportions gives the original casein with its characteristic physical and chemical properties.

Investigations of the solubility of casein in acids and bases show its complex nature. The solubility is, under constant conditions, a function of the amount of casein present as precipitate, and the dissolved substances differ in chemical compositions from the precipitate.

The fact that casein is a mixture makes investigations of its chemical structure difficult. Due to its high content of phosphorus and the importance of this to nutrition problems, the mode of combination of this element has been the subject for elaborate studies. Experiments show that the phosphorus in casein is present as phosphoric acid and—at least partly—bound to serine by an ester linkage. As the phosphorus content of the different fractions of casein is different, this problem is of importance to the explanation of the above-named physical properties.

Prof. T. P. Hilditch.—*The chemical nature of the glycerides of milk-fat* (11.50).

The methods available for the rapid characterisation and routine analysis of milk-fats are insufficient to give detailed information as to the fatty acids and glycerides present therein. The present knowledge of milk-fat acids and glycerides and of the procedures adopted in their study are briefly summarised. The available data permit some comparisons to be made between the milk-fats of cows and of other animals, and also suggest some of the ways in which the milk-fat components may be varied as a result of change in the diet of the animal, in its age, or in certain other factors.

Certain acids (e.g. butyric, caproic, palmitic, stearic, oleic) are present in important proportions in milk-fats, whilst others (some of which may be peculiar to milk-fats) are present in minute proportions. The recent work of Brown and others on some of the latter acids is described.

There is at the moment some uncertainty as to the presence of linoleic or other polyethenoid acids of the C_{18} series in butter fat, and this subject is discussed in the light of recent work.

Dr. S. K. Kon.—*The vitamins of milk* (12.10).

A study of the vitamin content of milk produced under conditions typical of the South of England practice has been in progress for the last three years at the National Institute for Research in Dairying, Reading. Biological tests have demonstrated marked seasonal variations in the total vitamin A activity and in the vitamin D content of milk. Physical measurements show a similar fluctuation in the carotene content. The concentrations of the vitamin B complex, vitamin B_1 and vitamin B_2 appear to be constant throughout the year and are not affected by the season. The amounts of vitamin A, B_1 and D present in milk at different seasons of the year are given in terms of the respective International Standards.

It has been shown in joint work with Drs. Moore and Dann of Cambridge that the $SbCl_3$ test for vitamin A cannot be applied directly to butter owing to the presence in the latter of an inhibitor showing seasonal variation. The inhibitor is removed by saponification. The total vitamin A activities of Shorthorn and Guernsey butters produced under identical conditions of feeding and management are equal. On the other hand, Shorthorn butter contains more vitamin A and less carotene than a corresponding Guernsey

butter. A biological estimation of the vitamin A activity of such butters coupled with physical measurement of their carotene and vitamin A content permits of a calculation of the vitamin A activities of carotene and of vitamin A *sensu stricto* (joint work with Mr. A. E. Gillam of Manchester).

When the chemical test for vitamin C (using the 2-6-dichlorophenol-indophenol reagent) is applied to bottled milk, marked day to day variations are noticed in the concentration of the reducing factor. These are due to the action of light transmitted through glass bottles. Vitamin C in milk is either rapidly destroyed by visible light or else it undergoes reversible oxidation, the product reacting no more with the vitamin C reagent.

The vitamin D activity of butters is to a large extent lost after saponification, under conditions in which the antirachitic factors of cod-liver oil and irradiated ergosterol are unaffected (experiments on rats). The loss in activity is more marked in autumn and winter butters than in summer butters.

Butter contains at least two factors of differing chemical stability, which are antirachitic for the rat.

Discussion (12.30). (Dr. N. C. Wright.)

SECTION C.—GEOLOGY.

Thursday, September 6.

The Geology of the Aberdeen District (10.0) :—

Prof. A. W. Gibb.—*Solid geology.*

Dr. A. Bremner.—*Surface geology.*

Mr. C. B. Bisset, Dr. S. Buchan, Miss Jean E. Imlay, and Mr. J. A. Robbie.—*On some granites of Aberdeenshire* (11.15).

It has hitherto been assumed that the grey granites of Aberdeen are of *Older* or pre-Torridonian age, while the red granites of Hill of Fare and Bennachie are *Younger* or Caledonian.

It is now suggested that the majority of the Aberdeenshire granite masses are of Caledonian age. Two divisions are recognised—an *Earlier* and a *Later*.

In the *Earlier* Caledonian group are the Skene complex, the Aberdeen, Garrol and Cairnshee granites. This group contains a series of rocks, which show a graded transition from a spheniferous quartz-mica-diorite through hornblende-granite and porphyritic biotite-granite to grey, two-mica, microcline-granite. A transition between the Skene and Aberdeenshire granites takes place by diminution of porphyritic character, alteration of phenocrysts from perthite to microcline, appearance of muscovite and change of colour from red to grey. Mr. Bisset has recorded that the evidence points to variation of rock-type being due to differentiation.

The Hill of Fare, Bennachie and Peterhead granites make up the *Later* group. This consists mainly of coarse, non-porphyritic, more acid, red, biotite-granites. Within the mass there is also variation. Coarse granite, rich in heavy minerals, has been intruded before finer, more acid granite in which the heavier minerals are scarce. Dr. Buchan notes that a granodiorite locally developed is due to interaction of granite and country-rock, while grey granites arise from reaction between red granite and mica-schists.

Dr. Stevenson Buchan.—*The petrology of the Peterhead and Cairngall granites* (11.45).

Two groups of granites, Cairngall and Peterhead, are recognised in the mass hitherto known as the Peterhead granite.

The Cairngall granite is a grey, porphyritic and slightly foliated rock. The Peterhead granite is a composite intrusion of red soda-granites (albite granites), of which three varieties are found. The earliest of these is a coarse-grained type, rich in heavy minerals and containing abundant inclusions. This variety, coming in contact with the metamorphic rocks, has developed locally a granodiorite characterised by idiomorphic hornblende and orthite. A finer-grained, more acid granite has been forced into the centre of the coarse type and was followed by the intrusion of dike-like microgranites.

The most prominent joints and faults trend a few degrees west of north, which is the direction of most of the microgranite dikes, or a few degrees north of east, which is the direction of porphyrite and felsite dikes.

The contact between granite and country-rock may be sharp, with no chilling or modification of the granite. Elsewhere a hybrid rock may intervene to form a perfect transition.

No ores have been found in the granite, and there is little evidence of tourmalinisation. A small amount of tourmaline occurs in pegmatites in the metamorphic rocks near the contact.

There is an aureole of metamorphism around the granites.

The granites were intruded towards the end of the Silurian or very early in the Old Red Sandstone period.

Mr. J. V. Harrison and Mr. N. L. Falcon.—*The effect of gravity on rocks in weathered simple folds : a factor in tectonics* (12.15).

In parts of South-West Persia the rocks were thrown into large simple anticlinal folds during the Alpine orogeny Later, these rocks, comprising massive limestones separated and succeeded by considerable thicknesses of incompetent strata, were subjected to differential erosion, which has unroofed the limestones and removed their support in places. The action of gravity upon the folded rigid rocks has produced strikingly abnormal large-scale structures, varying according to the attitude of the limestones. The structures include cascading dips, overturned flaps on the edges of the synclines, large recumbent folds, slip-faulted blocks, 'roof-and-wall' folds, etc. Similar features are liable to have been formed in the Laramide, Hercynian and Caledonian Revolutions—whenever, in fact, orogenesis had thrown the rocks of the earth's crust into folds of large amplitude. Bailey has produced evidence of rare structures caused by steep topography in submarine earthquake zones, and Jefferies has indicated the fundamental instability of towering piles of rock and their inherent tendency to flatten under the influence of gravity. The evidence examined by the authors shows that this process tends to occur when the surface relief is of the order of 2,000 ft. or more in limestone fold-mountains. Formerly such structures have been imputed to the action of tangential or rotational forces only.

Afternoon.

Excursion to Rubislaw Quarry, Garlogie, Gask Quarry, Dunecht, Castle Fraser, Craigearn, Kemnay Quarry, Craigmyle and Blackburn. Leaders : Mr. J. K. Allan and assistants.

Friday, September 7.

Presidential Address by Prof. W. T. Gordon on *Plant life and the philosophy of geology* (10.0). (See p. 49.)

Discussion on *The age of the Moine and Dalradian formations* (11.0).

Prof. H. H. Read.—*Introduction.*

In connection with the age-problems of the *Moine Series*, four different opinions are held :

(*a*) The Moine Series includes Lower Palæozoic rocks and received its metamorphic character during the Caledonian orogeny.
(*b*) The Moine Series is the equivalent of the Torridonian and was metamorphosed in post-Cambrian times.
(*c*) The Moine Series is post-Lewisian but pre-Torridonian, and its metamorphism is pre-Torridonian in age.
(*d*) The Moine Series and its metamorphism are Lewisian in age.

The bearing on these views of new evidence from Sutherland and elsewhere is indicated. Resemblances between Torridonian and Moine rocks adjacent to the post-Cambrian dislocations are due to metamorphic convergence, and indicate neither that the Moine general metamorphism is of post-Cambrian date nor that the Moine Series is the equivalent of the Torridonian. The relations and affinities of the Ben Loyal alkali-syenite of North Sutherland show that the general Moine metamorphism is earlier than the post-Cambrian movements—a conclusion confirmed by the examination of the belt of low-grade metamorphism in the Moine Series near the great post-Cambrian dislocations. The two metamorphisms of the Moine rocks may be both of Caledonian date or they may be separated by a great interval of time.

In Central Sutherland, the Moine Series is invaded by metamorphosed ultrabasic and basic intrusions that are identical with the pre-Torridonian intrusions in the Lewisian Gneiss of the unmoved foreland. This suggests that the Moine Series and its metamorphism are of pre-Torridonian date. Further, in that district, the Hornblendic Rocks of Durcha Type, which are of Lewisian facies, form an integral part of the Moine Series, and the three rock-groups—Moine Series, Rocks of Lewisian Type and Hornblendic Rocks of Durcha Type—are there one and indivisible. But the evidence for the inlier-character of the Lewisian Rocks of Ross-shire has still to be reckoned with, and the conclusion that the Moines may be of Lewisian age cannot be advanced till this evidence has been re-examined in full.

Few data are available concerning age-relations in the *Dalradian Series*. The correlation of the Struan Flags with the Moines is accepted and leads to the conclusion that the Moines and Dalradian are transitional. There are, however, many views opposed to this conclusion. The ' Lennoxian ' of Gregory has no existence in North-East Scotland. With regard to the relations between metamorphism and folding in the Dalradian area, it is considered that no conclusions can be reached till detailed field and petrographical work has been done.

Prof. E. B. Bailey, M.C., F.R.S.

The straight bedding of most of the Moine rocks shows that these are not, in the main, merely metamorphosed equivalents of the Applecross Group of the Torridonian, as the latter are intensely current-bedded arkoses. But

metamorphosed current-bedded arkoses are found among the Moines of Ardnamurchan.

The retrogressive metamorphism of the Moines near the Moine Thrust did not carry the implication of a Pre-Cambrian age for the main Moine crystallisation, in the opinion of Peach, and the speaker agrees with this view.

While Read's interpretation of the Tarskavaig Moines, as being unusually highly metamorphosed Torridonian rocks, is consistent with Teall's view, Clough was equally certain that they are unusually lowly metamorphosed Moines.

Near Loch Borolan sheared sills, apparently belonging to the Assynt complex, are found on both sides of the Moine Thrust, which suggests that some of the sills were intruded after the Moine Flags had moved into the district. Thus the intrusion of the Assynt complex cannot have entirely preceded the thrust movements.

The appinite suite, referred to by Dr. Phemister, has been shown by Wright, in Colonsay, to be of intermediate age in relation to two suites of movements, both of which are presumably referable to the Moine Thrust series.

Dr. R. Campbell.

Dr. Gertrude L. Elles, M.B.E.

In the extreme south-west of the area, the Tayvallich Boulder Bed contains boulders of Moine types of rock. The boulders of alkali-rich igneous rocks come in above, also a great series of highly metamorphosed schists and gneisses, closely resembling those of Islay. Quartzite boulders are also found, and the evidence of these included rocks points strongly to the conclusion that the Moines must be pre-Dalradian.

Prof. P. E. Eskola.

The Moinian and Dalradian bear little resemblance to the metamorphosed Cambrian-Silurian of Scandinavia, but in both Sweden and Finland the Jotnian Sandstones are similar in every respect to the Torridonian, and almost certainly of the same age. In eastern and northern Finland the Karelian Zone of metamorphic rocks stands in the same relation to the Jotnian as the metamorphosed Cambro-Silurian of Scandinavia to the O.R.S. The Karelian Zone is closely comparable with the Dalradian, and includes quartzites, slates, mica-schists and limestones, cut by numerous sills and dykes of basic intrusives. Dr. Mikkola has recently mapped in the eastern and western parts of central Lapland sedimentary formations much like the Moinian, and probably older than the Karelian lying between the two areas. The plutonic intrusives in the Karelian are, however, Pre-Cambrian, and even Pre-Rapakivi in age, while those in the Scottish Highlands are Caledonian. It is consistent with the theory of geosynclines and recurrent periods of orogeny to suppose that sediments of similar lithological types may well have been deposited between the close of the Karelian and the Caledonian orogeny, as during the next older Pre-Cambrian orogenic period, i.e. up to the close of the Karelian. In Scandinavia the Eocambrian Sparagmite Group perhaps correlates with parts of the Dalradian, and it may be significant that the tillite of Varangerfjord, formerly regarded as Ordovician, has been recently shown by Holtedahl to be Eocambrian. The Boulder Bed at Schiehallion, with its interesting pebbles, is very like

the Varangerfjord tillite. Summarily, the Moinian and Dalradian formations would appear to be Caledonian in the wide sense, including sediments of Eocambrian age, and possibly still older Post-Karelian rocks.

Prof. H. von Eckermann.

In Sweden, recent work has divided the Pre-Cambrian into five great groups :

1. The Leptites, being the oldest known volcanic and sedimentary rocks, cut by the oldest known granites.

2. Archæan sediments, phyllites and quartzites, proved through mapping in the Loos area to rest unconformably on the old leptite-granite surface.

3. Late-Archæan, consisting of plutonic and volcanic rocks, followed by later sediments.

4. Pre-Jotnian Series, also largely igneous, with their graded erosion products.

5. Sub-Jotnian Series, porphyries, porphyrites and rapakivi granites, followed by the Jotnian red sandstones and shales.

Each of these groups is separated from the next by an unconformity and well-developed conglomerates. Above the Jotnian sandstones come the Eocambrian Sparagmite, followed by the Cambro-Silurian and non-fossiliferous sandstones of probably Devonian age. The Sparagmite locally shows a marked resemblance to parts of the Moines, but the speaker believes the Moines are absent from Sweden, with the possible exception of some granulites near the Finnish border, mentioned by Eskola. Similarly, the Torridonian rocks are similar in their mode of occurrence to the Jotnian sandstones, but look younger. The only part of the Highlands which closely corresponds with any part of Sweden is the area of the Lewisian, which is closely similar to the great gneiss area of south-western Sweden. These the speaker regards as highly metamorphosed equivalents of Groups 1 and 2 above.

As a satisfactory correlation between Sweden and Finland has not yet been reached, and as there are still many points of difference in regard to the correlation of Sweden and Norway, it is at present very risky to attempt to correlate Sweden with the British Isles.

Dr. M. Macgregor.

The alkaline sills, presumably of post-Cambrian age, which occur east of the Moine Thrust, are sheared in agreement with the country rocks. This fact has been used as an argument for the post-Cambrian age of the metamorphism, but no evidence that the sills were intruded into unaltered sediments has been put forward, and the shearing must be regarded as due to the thrusting movements that produced the mylonites.

The speaker agrees that the 'rocks of Lewisian type' in central Sutherlandshire are an integral part of the Moines, and that certain of the rock types in the former can be matched in the Lewisian of the foreland ; but as an assemblage the rocks of the Lewisian of Sutherlandshire do not resemble the banded and often sheared orthogneisses of the foreland.

Strong evidence that the Moines rest unconformably upon the Lewisian has been obtained by the detailed survey of Ross-shire and Inverness-shire. Here the Lewisian contains graphite-schists and calcareous rocks of various kinds that are absent from the neighbouring Moines. The fact that the stratigraphical relation between the Moines and the Lewisian of Ross and Inverness is different from that between the Moines and the 'rocks of

Lewisian type ' in central Sutherland is a formidable obstacle to the view that Lewisian rocks of the two areas are identical. If the very strong evidence of the inliers is accepted, the Moines must be younger than the Lewisian.

Transitional types between the Moines and Dalradians have been described from several localities, and elsewhere the line of separation between them is a structural break ; thus the age of the Moines cannot be considered separately from the age of the Dalradians. Much more work on the genesis and history of the schists and on the time-relations of the various intrusions and injection complexes is necessary before the problem may be solved.

Dr. J. Phemister.

Prior to the intrusion of the Carn Chuinneag complex the Moine sediments were gently folded along east-west axes, and had possibly been already intruded by basic sills, in pre-Caledonian times. The Carn Chuinneag complex caused thermal metamorphism of the Moine sediments, which, in early Caledonian times, were folded isoclinally along N.N.E. to S.S.E. axes, and were metamorphosed into schists and granulites. Reference of these events to early Caledonian times is based on the argument that, if the Caledonian earth-movements were not responsible for the isoclinal folding, they had no effect in northern Scotland other than the production of the great overthrusts, and minor folding ; also that no parallel system of folding is known in the Pre-Cambrian of N.W. Scotland, except a very early Archæan folding of a broad, gentle type, seen in places in the Lewisian gneiss. The next episode was of considerable duration, and was mainly later than the folding, though still of early Caledonian date. To this episode belong the regional concordant granitic intrusions.

In late Caledonian times the Ben Loyal syenite, the Ach'uaine Hybrid and Appinite Suites were intruded.

The thrust dislocations and the minor folding and rodding along N.W. to S.E. axes followed ; while finally the great granitic and granodioritic stocks were injected, possibly continuing into Lower O.R.S. times.

Prof. Read's argument for the pre-Torridonian age of the Moine metamorphism is considered invalid because his petrographic comparisons of gneisses in the Moine and Lewisian formations are drawn between rocks possessing different geological histories.

Prof. C. E. Tilley.

Afternoon.

Excursion to Methlick, Tanglanford Bridge, Ythanbank, Auchedly Bridge, Tarves, Craigie, Rocks of Balmedie Quarry, Belhelvie Village and Tarbothill. Leaders : Prof. A. W. Gibb and Prof. H. H. Read.

Saturday, September 8.

Excursion to Potarch, Birse, Dinnet, Deecastle, Inchmarnoch, Dinnet Bridge, Mill of Dinnet, Ferrar, Dinnet Village, Burn o' Vat, Ordie, Dinnet and Aboyne. Leader : Prof. H. H. Read.

Sunday, September 9.

Excursion to Stonehaven Harbour, Dunnottar Castle, Burn of Benholm. Leader : Dr. R. Campbell.

Monday, September 10.

Discussion on *Underground water supply* (10.0) :—

Prof. W. S. Boulton.—*Introduction.*

(Ordered by the General Committee to be printed *in extenso.* See p. 456.)

Prof. P. G. H. Boswell, O.B.E., F.R.S.

The speaker desires to emphasise, as Prof. Boulton has done, the frequently urged necessity for a national survey of water resources, including the systematic recording of underground water-levels and flow from springs. The need for a survey and proper recording of both underground and overground supplies has been repeatedly recommended ; it was so as recently as last year by the Inland Water Survey Committee of the British Association (a joint committee of Sections A, E, and G) and was the *raison d'être* of a deputation from the Association and the Institution of Civil Engineers to the Ministry of Health in July of this year (*v.* the Committee's Report). In order that such a survey of possible underground resources may be rendered effective, it is imperative that there should be compulsory registration of all wells and boreholes of more than 100 ft. in depth, just as similar shafts and borings in connection with mining operations are registered under the Mining Industry Act. The only addition to the data which Prof. Boulton regards as essential for the proper understanding of the problem, that occurs to the speaker, is the recording of the depression of water-level in each borehole in various rock-formations in relation to the varying amounts of water pumped. Among the many practical questions on which the survey would throw light are the serious and persistent fall of underground water-level and (to take a topical example) the consideration of the most effective and least expensive methods of dealing with local shortage of supplies resulting from drought conditions.

The investigation of underground water is not concerned only with its recovery for domestic and industrial consumption (a steadily increasing demand). As is well known, it is necessary for the effective disposal, as a temporary or a permanent measure, of undesirable supplies, and for the safe and economic prosecution of large-scale engineering undertakings.

Sir A. E. Kitson, C.M.G., C.B.E.

Before the Conference of Corresponding Societies the speaker urged that compulsory registration with the Government should be made of all boring and well-sinking operations below 100 ft., as is the law at present in relation to similar operations for minerals. The tabulation of information respecting the nature of the strata passed through during boring and well-sinking is highly desirable, but it is not legally compulsory. These operations for water afford excellent opportunities of obtaining valuable information, and full advantage should be taken of such opportunities.

Although the people operating the plants are not geologists, they can give information of value, leaving the geologists to furnish the details of the strata. The Geological Survey of Great Britain can supplement such information, but only if they are notified of the operations. There are, besides, numbers of amateur as well as professional geologists dispersed through the country, who may be depended upon to assist in such work. Further, the members of Corresponding Societies can also give assistance by notifying the Geological Survey of such operations in their districts.

Co-operation and co-ordination in this manner will give valuable information, at present obtainable in only a few cases, and so be of much economic value to the country.

It is important to get evidence of the character of the hidden Chalk in the London basin, more particularly with regard to the function of the joints and fractures, which may divert the water falling in the Chilterns to the surface as springs, or may give rise to local storage-basins underground.

With regard to additions to supplies of water in the London basin, the speaker suggested continuous diversion into boreholes in the Chalk at suitable places of small portions of the streams flowing in the valleys, after the water had been sterilised. Such refilling of the basin would counteract the tendency to draw polluted Thames water into it, to the great detriment to health, but a very real danger owing to the greatly lowered level of the water under London.

Prof. W. G. Fearnsides, F.R.S.

The underground water problem as it affects the industrial regions of W. Yorkshire and the S.E. Pennine area is discussed. The importance of joints in the Carboniferous and older rocks for water storage within the formations, and for conducting unfiltered water to particular borings, shafts and wells, is stressed. The influence of rock composition and rock texture, more especially inter-grain porosity, on the water-bearing properties of the newer geological formations, is noted, and the author refers to the distribution of geological structures and their effects upon the disposition of wells and troublesome waters in the coal mines of the exposed coalfield area. Reference is made to the special precautions taken when sinking shafts through the Magnesian Limestone and Trias which lie above the Coal Measures in the concealed portion of the field that is now being developed. The composition of the water obtained from certain of the Bunter wells of the Midlands, more particularly those which must be increasingly exploited as the Doncaster coalfield and its industries expand, is discussed.

Prof. G. Hickling.

Mr. L. H. Tonks.

Dr. S. W. Wooldridge.

The marked variations of rainfall which have occurred in the past, and which will certainly recur in the future, enforce the urgency of a systematic investigation of underground water resources. The great drain on water supplies during the nineteenth and twentieth centuries has occurred during a period of generally high rainfall, not to be regarded as representing average conditions. Even though underground water cannot, in the long view, be regarded as an alternative to a water grid fed from the wetter west, it will always be capable of affording supplementary supplies. But the exploitation of these latter will demand a much more detailed knowledge of regional hydro-geology than can be gathered from existing data. Something more than the useful records of the *Water Supply Memoirs* of the Geological Survey is required. These are largely records of past attempts, successful or unsuccessful, to find water. For vast areas of country there is practically no hydro-geological information of any kind available. These blanks can be filled only by deliberate investigation carried out concurrently with a greatly accelerated 6-in. primary geological survey. The sinking

of exploratory narrow-gauge borings at selected critical stations should prove both feasible and profitable in the course of such work.

AFTERNOON.

Excursion to Insch, Auchenbrodie, Den of Wraes and Wardhouse. Leader: Prof. H. H. READ.

Tuesday, September 11.

Mr. K. P. OAKLEY.—*Pearl-like bodies in certain Silurian Polyzoa* (10.0).

Spheroidal bodies bearing a remarkable resemblance to minute pearls, on account of their opalescent lustre and fine concentrically laminated structure, occur in the zoœcia of Ceramoporoid Polyzoa from the Wenlockian beds of Cardiff, Dudley, etc.

They were interpreted by Etheridge and Foord as chalcedonic infillings of mural-pores, and by Dr. Bassler as extraneous silicified ooliths. Their true nature as internal calculi, probably formed during the lifetime of the polyzoa, was hinted at many years ago by Prof. Sollas.

Detailed investigation has shown that these spheroliths are composed of calcium carbo-phosphate (*dahllite*) deposited from solution in thin concentric layers round nuclei. Their occurrence in the zoœcial tubes, completely sealed in by the continuous diaphragms and unaccompanied by detrital material, makes it evident that they were formed *in situ*. Their restriction to the members of one or two closely related genera is indicative of a control effected by the anomalous biochemical nature of the body-fluids of these particular forms. It is suggested that the spheroliths are analogous to urinary calculi, and that essential factors in their formation were practical absence of ' buffering ' in the body-fluids and a substantial rise in their *p*H value during the degeneration of the polypides. The conditions postulated have been reproduced experimentally and comparable results obtained.

Dr. A. RAISTRICK.—*The microspores of Carboniferous coals* (10.25).

By the use of solvents, the microspores of coal-forming plants have been extracted from coal in quantities sufficient to allow of statistical treatment. Over forty different varieties of microspore are recognised, and an attempt has been made to study their distribution through the coal seams of both lower and upper Carboniferous age, in Northumberland and Durham. Their use for the correlation of coal seams has been tested over a wide area and a large number of seams, with encouraging results.

Several problems of theoretical interest, relating to the coal-measure floras, are suggested by this study.

Mr. D. J. SCOURFIELD.—*The animal remains in the Rhynie Chert* (11.0).

So far, all the animal remains found in this Middle Old Red Sandstone chert belong, with one or two doubtful exceptions, to the Arthropoda, of which three classes are represented definitely, viz. Crustacea, Arachnida and Insecta, while the Myriapoda are doubtfully represented by a single specimen the true nature of which has still to be determined. The single species *Lepidocaris rhyniensis* Scourfield represents the Crustacea, but is placed in a new order, viz. Lipostraca. The Arachnids are represented by *Protacarus crani* Hirst, belonging to the order Acari ; by a single specimen of *Palæocteniza crassipes* Hirst, thought to be one of the Araneæ ; and by

two genera and a number of species belonging to the Anthracomarti. These are grouped into a new family, Palæocharinidæ, and comprise *Palæocharinoides hornei* Hirst, *Palæocharinus scourfieldi* Hirst, *P. rhyniensis* Hirst, *P. calmani* Hirst, *P. kidstoni* Hirst, and a dozen other forms not specifically named. A supposed Eurypterid, *Heterocrania rhyniensis* Hirst and Maulik, is represented by fragmentary remains, and was apparently of very small size. The class Insecta is definitely represented by forms of Collembola, named *Rhyniella præcursor* by Hirst and Maulik, who have also figured the jaws of another insect in the larval form, which Tillyard has named *Rhyniognatha hirsti*.

Dr. B. H. Knight.—*The economic uses of some Aberdeen granites* (11.30).

These granites are widely used in building and in road-making, and the paper describes a recent application of the Rosiwal method of mineralogical analysis whereby the suitability or otherwise of any particular type for such uses can be determined. The acid plutonic igneous rocks are shown to possess certain structural and textural features which materially affect this question, one of the most important of which is the prevalence of fissuring, usually only discernible by microscopic means, but clearly visible by staining methods, which is peculiar to this class of rocks only. A colorimetric test applicable to the class has been worked out, and the method of measuring the amount of fissuring present is described. Possible explanations as to the cause of the fissuring are discussed, comparisons between the amount of fissuring present in the commoner Aberdeen granites and those from other localities are made, and the paper concludes with a short appendix describing the method of impregnation and staining of the specimens and slides.

Prof. W. N. Benson.—*The Ordovician rocks of New Zealand* (12.0).

Fossiliferous Ordovician argillite associated with greywacke and quartzite occur in the north-western and south-western extremities of the South Island. Field studies by several workers, and palæontological investigations, chiefly by Keble, have resulted in the quadrupling during the last decade of the list of known fossils (now over 130 species), and of distinct faunal associations. The development of graptolites is similar to that in Victoria. In the Lower Ordovician rocks have been found in regular stratigraphic succession eight faunal associations comparable with those occurring within the Lancefieldian, Bendigonian and Castlemainian Series of Victoria, which Dr. Elles considers the equivalent of the *Dichograptus* and *D. extensus* zones of the Skiddaw Slates. The higher Ordovician beds, among which is some limestone, are approximately equivalent to the Gisbornian Series of Victoria, or the Llandeilian of Britain. There is a richly fossiliferous lower assemblage, and two scanty higher assemblages. A *Protospongia*, a few phyllocarids and brachiopods described by Chapman, and two trilobites described by Reed, mostly of Lower Ordovician age, complete the known fauna. The passage from the normal sediments into crystalline schists has been traced in petrographic detail.

Prof. W. N. Benson.—*The Devonian period in Australia* (12.30).

The paper briefly summarises the character and distribution of the various formations of this age throughout Australia, indicating their palæogeographic significance.

Afternoon.

Excursion to Bay of Nigg, Cove Quarry, Bothiebriggs, Cammachmore, Shielhill, Tarbothill and Blackdog. Leader : Dr. A. Bremner.

Wednesday, September 12.

Mr. A. T. J. DOLLAR.—*The petrology of certain dike rocks of high magnetic susceptibility* (10.0).

In 1933 relatively large magnetic anomalies were detected while making traverses above basaltic and doleritic dikes hidden beneath an overburden of 9 in. to 10 ft. of soil on Lundy, Bristol Channel.

Samples of these dikes were collected and examined petrographically by the author, while the magnetic mass-susceptibilities (i.e. the respective magnetic susceptibilities per unit volume—measures of the magnetising effects of particular magnetic fields upon specimens placed in them—divided by the respective densities of the specimens ; both sets of quantities being expressed in appropriate units) of (*a*) small rectangular bars of square cross-section, cut from these rocks, and (*b*) powdered samples of the same, were determined by Prof. E. Herroun, using a modified Curie balance and magnetic fields of suitable strengths.

The numerical values so obtained prove to be related in an interesting manner to (*a*) the kinds, proportions and distributions of iron-bearing minerals in the dikes, especially magnetite, hæmatite and ilmenite ; (*b*) states of weathering in the rocks ; (*c*) magmatic differentiation, including the sorting of iron-rich minerals by convection currents ; (*d*) directional magnetic properties acquired in the earth's magnetic field, or as a result of conducted lightning discharges ; (*e*) data obtained from magnetic measurements made with the vertical magnetic force variometer.

The unusually high value of 4230×10^{-6} c.g.s.u. for the magnetic volume-susceptibility of a sample from dike No. 21, East Side, Lundy, using a magnetic field-strength of 78 c.g.s.u. in the measuring instrument, is especially noteworthy in relation to the character and content of its iron-bearing constituents.

Mr. S. J. TOMKEIEFF.—*The British Carboniferous-Permian igneous province* (10.30).

Statistical methods are applied to the study of the late Palæozoic igneous rocks, mainly in the midland valley of Scotland and the Borders. The material comprises 254 chemical analyses (recorded and unrecorded) and 126 modal analyses (including 80 new analyses).

According to relative age the rocks are divided into the following series :

1. *Alkalic series.*—Olivine-basalts, Mugearites, Trachyandesites, Trachytes, Felsites. Mainly lavas of Lower Carboniferous age.

2. *Peralkalic series.*—Picrites, Picro-teschenites, Teschenites (Theralites), Lugarites, with a transitional series of Basanites, Crinanites, Essexites. Late Carboniferous or early Permian intrusives.

3. *Calc-alkalic series.*—Quartz-dolerites with segregation veins. Probably early Permian intrusives.

The modal analyses refer mainly to the olivine-basalts, which, although forming a continuous series, can be subdivided into three groups according to the relative proportions of pyroxene and feldspar (olivine and iron ores do not show any significant variation) :

(1) Pyroxene-rich group—Hillhouse and Craiglockhart types.
(2) Intermediate group—Dalmeny and Dunsapie types.
(3) Feldspar-rich group—Jedburgh and Markle types.

The first group grades into the Basanites (including monchiquites, etc.), while the third group passes into a more acid and a more alkaline group of

Mugearites. The differentiation series proceeds to the Trachytes, which apparently split into a more alkaline group of Phonolitic trachytes and a more acid group of Felsites.

The major portion of the alkalic series can be interpreted as a result of crystallisation differentiation from a basaltic parent magma. The end-products (Phonolitic trachytes and Felsites) are probably due to the migration (convection) of alkalies and volatiles.

The members of the peralkalic series have resulted from an early gravitational differentiation (olivine sinking) together with the squeezing out of the residual liquid at the last stage of solidification (segregation veins of lugarite, analcite-syenite, etc.).

The members of the calc-alkalic series are entirely due to the squeezing out of the residual liquid.

The origin of the three principal series is explained by the migration of alkalies and volatiles in the primary basaltic magma, which itself is the source of the first series. The upward migration of alkalies and volatiles probably occurred at the end of the volcanic period in consequence of the relief of pressure. The concentration of alkalies and volatiles in the upper zone of the magmatic reservoir gave rise to the peralkalic sub-magma, while the lower de-alkalinised zone produced the late calc-alkalic sub-magma.

Dr. F. Walker.—*A limestone-diorite contact near Dorback Lodge, Inverness-shire* (11.0).

The granite mass of Dorback to the north of the Braes of Abernethy exhibits a well-marked dioritic facies towards its eastern margin. This relatively basic rock is associated with a thick band of limestone which has apparently been caught up in the magma. While there is no evidence of extensive assimilation, a well-exposed contact in a stream section shows some interesting phenomena on a small scale.

Analyses show that the diorite becomes richer in iron oxides, lime and potash towards the contact, while under the microscope hornblende is seen to give way to green diopsidic pyroxene. The limestone is richer in iron oxides and magnesia towards the margin, and this increase in ferro-magnesian content is accompanied by a greater development of lime-silicate minerals.

The contact aureole of the granite contains some unusual mineral assemblages of which the most notable is a cordierite anthophyllite rock.

Dr. R. Campbell and Dr. I. M. Robertson.—*Glacial and interglacial deposits at Benholm, Kincardineshire* (11.30).

Near the farm of Upper Birnie, over 200 ft. O.D., and 1½ miles from the sea, the drift deposits in the Burn of Benholm show the following succession : (*a*) Gravel, (*b*) Red boulder-clay, (*c*) Interglacial gravel, sand and peat, (*d*) Black shelly boulder-clay, with, at one point, stratified shelly sand and gravel intervening between the boulder-clay and the country rock.

The shelly boulder-clay contains numerous arctic shells, usually broken and striated ; the boulders include chalk and other Mesozoic limestones, chalk flints, jet, etc. The included boulders indicate transport from the north-east.

The interglacial sands and gravels are sometimes contorted. The peat, which has a maximum thickness of about 15 cm., shows several well-defined changes in structure and composition. The lower layers merging into the lower boulder-clay are black and well decomposed, and contain much silt.

This, combined with the fact that they contain nymphæa pollen, would indicate a marshy land surface. From this point upwards there are various alternating layers of dark and lighter coloured material, most of which is well humified. There is a sharp line of demarcation between the peat and the upper boulder-clay.

The pollen analyses show that the chief tree species present are Pinus and Betula, the lower layers containing from 60 to 80 per cent. of the former and from 25 to 35 per cent. of the latter. In the upper layers the position is reversed, the Betula rising to over 60 per cent., while the Pinus falls to under 20 per cent. Alnus and Quercus occur throughout the profile, and in the upper layers Ulmus and Corylus are also found. The marked change in the Pinus and Betula figures about half-way up the section accompanies a change in the character of the peat, and would seem to indicate a marked change of climate.

The frequency of the pollen is low in all cases.

The upper, red, boulder-clay is the bottom moraine of the ' Strathmore ' ice-sheet which, at this locality, had a north-easterly movement ; the overlying gravels are fluvio-glacial and were deposited during the retreat of this second ice-sheet.

Mr. M. B. Cotsworth.—*The glacial cause of changing climates* (12.0).

Since the present author's paper on changing climates at the meeting in 1906, so much more information concerning changes of climate has been gathered in Alaska, Canada, Western Asia, West Africa and other countries, that it seems advisable that the evidence of geologists, climatologists and government surveyors should be co-ordinated by a Research Committee appointed by the British Association to consider and report upon this world-wide subject, which has developed beyond the scope of individual research.

Official photographs are produced showing that great glaciers in Alaska have been melted back at the rate of about half a mile per year. The Sahara Desert has been drifting southwards across the Nigerian boundary. The Dead Sea has been dried up so far by evaporation that Jericho is now many miles north of the river Jordan's outfall into the Dead Sea.

Palestine has become more arid, as have all the countries northward to the Siberian Railway. Similar changes are progressing in South Africa and Australia.

From such indications the writer forms the opinion that the gravitational weight of the increasing Ice-cap in Greenland, Baffin Land, etc., indicates that the Glacial Period is continuous and that its variations during many thousands of years dry up vast areas while other parts are increasingly watered and renewed by the very slow but ever varying changes of climate.

Dr. C. A. Matley.—*A 50-ft. platform in North Wales*. (Taken as read.)

An account is given of a 50-ft. platform or terrace which is well developed on the Lleyn Peninsula (Carnarvonshire) around Pwllheli, Llanbedrog, Abersoch, Llanengan, Afon Wen, etc. A similar feature is believed to be present at both ends of the Menai Straits and at Llandudno.

Its inner margin stands at about 50 to 56 ft. O.D. and it slopes gently seaward. It consists largely of gravels and sands with much glacial material ; no organisms or artifacts have been found in it. Its age is discussed with reference to the glacial history of the Lleyn Peninsula and its relation to the glacial overflow channels of that area. In part the terrace abuts against

sands and gravels laid down during an episode of Glacial retreat, and it seems probable that the platform was formed during a later episode of that retreat.

SECTION D.—ZOOLOGY.

Thursday, September 6.

PRESIDENTIAL ADDRESS by Dr. E. S. RUSSELL, O.B.E., on *The study of behaviour* (10.0). (See p. 83.)

Dr. D. S. MACLAGAN.—*Cycles in insect epidemics* (11.0).

Dr. A. E. CAMERON.—*The biology of the Scottish Tabanidæ* (11.30).

Three genera of Tabanidæ occur in Scotland—*Tabanus*, *Hæmatopota* and *Chrysops*. The little-known life histories of these flies have been investigated on account of their economic importance and in the hope that light might be thrown on the taxonomy of the group.

Hæmatopota pluvialis, the Cleg, is the most prevalent species. Its larva has been hatched and reared. The larva is carnivorous and cannibalistic. Experiments on the peculiar organ of Graber, which is present in the posterior part of the abdomen of the larva, indicate that its function is the perception of vibrations. Such a function must be of great use to the larva in its natural environment in the soil.

Adults of this species were induced to pair and lay eggs in the laboratory. The eggs were laid in masses of about one hundred and fifty, on leaves of grass or on the sides of the glass jar in which the flies were living. Oviposition followed a blood meal at an interval of ten days. A second oviposition may follow a second blood meal, but the second egg-mass is usually smaller.

The life histories of several other species have been investigated. Some of these species are pests in the straths and glens of the Highlands and along the shores of lochs. These species lay egg-masses, which vary in form with the species. The larvæ of most species will feed on meat, but that of *Chrysops relicta* refused this diet. In this species the life history may last two years.

Dr. J. F. G. WHEELER.—*Drift-bottle work round Bermuda and its connection with the flora and fauna of the surrounding waters* (12.0).

The Bermudas lie in lat. 32° 19′ N. and long. 64° 49′ W. within the western border of the Sargasso Sea. Interest in the tides and currents of the islands was stimulated by one of the Governors, and a paper was published in 1844 based upon the reports of pilots and sea captains, but the results are confused.

It is known in Bermuda that the Sea Bottle (*Halicystis*) is washed up on the south shore beaches from May to July, and it has been found that in the winter the Sargasso weed fauna is much sparser than it is in summer, some species of fishes and flatworms being entirely absent. The direction of drift of thirty-seven bottles recovered out of 530 liberated during two years suggests that during the winter the surface drift is from the north, and during the summer from the south-west. *Halicystis* lives in the Sargasso weed and is brought in by the summer drift, which also brings large numbers

of animals, while the winter drift carries old weed to the islands from which the animals have to a great extent disappeared.

Reports of Research Committees (12.45).

Afternoon.

Dr. S. M. Manton.—*Peripatus* (2.15).

Dr. D. S. Raitt.—*Fishing intensity and stock replenishment in the haddock* (2.45).

Investigations into the factors governing fecundity in North Sea haddock have shown that, in fish of the same age, egg production is proportional to a power of length slightly greater than the cube, while in fish of the same length the older the specimen the greater the number of eggs produced, the difference being most noticeable in two-year-olds as compared with three-year-olds. At the age of two, moreover, only about 10 per cent. of the females and 60 per cent. of the males of a year class mature. At three about 75 per cent. of the females and 95 per cent. of the males are spawners, and it is not till the age of five in males and six in females that all surviving members of a brood have ripened.

Such is the efficiency of the modern trawl that haddock come under its influence when they are about eighteen months old. Only a negligible percentage escapes capture to reach large size. The brunt of stock replenishment falls upon small fish of two and three years of age, for which task they are of greatly inferior capabilities.

Dr. Henry Wood.—*The relationship between the herring caught on the Scottish drift-net grounds and those caught by trawl on the Fladen ground* (3.15).

The herring population in Scottish waters is made up of at least two distinct race components, spring spawners and autumn spawners, which differ not only in their spawning times, but also to some extent in their distribution. Morphologically they are distinguishable from each other by differences in the numbers of vertebræ and keeled scales. The first shoals which appear on the drift-net grounds in May and June in search of food are mixed, containing varying proportions of the two components. About mid-July a redistribution of the shoals takes place. Maturing autumn spawners migrate to coastal areas and spawn in August and September. At the same time a large concentration of herring takes place on the Fladen ground, where spawning does not take place. These two communities, which incorporate closely allied components, remain apart throughout the rest of the drift-net fishery, so that the results of the trawl fishery for herring on the Fladen ground have no effect on the drift-net catches until the following May and June, when the shoals in quest of food are due to return again to grounds which lie within range of the drifter fleets.

Dr. S. G. Gibbons.—*Copepods with reference to herring fishery problems* (3.45).

Introductory remarks on the group. Food value owing to oil. Copepods form main food of the herring in Scottish waters in summer and, of all Copepods, *Calanus* is by far most abundant. Study of *Calanus* therefore useful and necessary, and the possibility at once arises of correlating plankton

and herring shoals. The life history of *Calanus* is complex, and length of life of various stages still open to doubt.

Important above all is the movement of the swarms of *Calanus*, for they are far from being regularly distributed in the sea and depend for their movements upon currents of the ocean. It is now established that there is a spring influx of *Calanus* into the North Sea and a small winter population in that area. Data give some idea of the intensity of the influx (1933 data from *Explorer*).

In spite of the small size of this animal some idea of its importance as food may be gathered when it is realised that the oil available from these crustacea alone in the N.E. Atlantic in spring would, if it could all be collected, have to be reckoned in millions of tons weight per month.

Friday, September 7.

Prof. J. Versluys.—*The distribution of marine animals and the history of the continents* (10.0).

If, trying to reconstruct the history of the continents, we look for indications given by the distribution of marine animals, we must consider such groups as can be presumed to be conservative in their distribution. This conservatism may be expected when the means of distribution are very limited, as in deep-sea corals, for instance, in the family of Primnoids, Gorgonacea, living on the continental slope. A southern fauna of Primnoids may clearly be distinguished from a circumtropical one, and the mixing is very limited, though the oceans are now in open communication, with continuous coastlines. This is in accordance with Wegener's theory, that presumes the southern Atlantic to be of rather recent origin.

The southern fauna is found on the coastal slope of the southern part of South America, on the southern coast of Australia and near some intermediate islands—but not on the coast of South Africa. This is not in accordance with present conditions, but again fits in with Wegener's theory. Wegener assumes that Australia and South America were formerly lying much closer together as parts of one continent. The present distribution of southern forms on so widely separated coasts has been caused by the splitting up of this continent.

Prof. A. Reichensperger.—*Probability of species-transformation in South American Myrmecophiles* (11.0).

Mr. G. E. H. Foxon.—*Functional adaptation in crustacean larvæ* (11.30).

In the Decapod crustacea there is a primitive scheme of development, variations of which are found in different groups. These variations are seen to be intimately related to function. This primitive scheme consists firstly of naupliar stages where the head appendages are the swimming organs ; these stages are followed by those in which the thoracic appendages are the swimming organs, and then finally the pleopods take on this function. In most Decapoda the nauplius is suppressed : this means that the stage in which the thoracic appendages are natatory is not already committed to forward movement. Movement is found to take place in directions other than forwards, and this is correlated with the existence of the respiratory current which flows from behind forwards. Movement in directions other than forwards makes functional continuity between the stages in which the thoracic appendages are natatory and those in which the pleopods subserve this function impossible. 'Metamorphosis' between these stages

is the result. Among the Stomatopoda, however, in *Lysiosquilla* the swimming function is seen to be passed gradually from the thoracic appendages to the pleopods. It is suggested that this orderliness of development is due to the absence of a respiratory current in the Stomatopoda.

Mr. A. G. Lowndes.—*The movement of ostracod spermatozoa as shown by the cinematograph film* (12.0).

Fresh-water ostracods possess both relatively and absolutely the largest sperms known throughout the animal kingdom. Their length may be as much as ten times the length of the adult male.

If these sperms are taken from the male they show no sign of movement, but if they are taken from the spermatheca of the female they are highly motile.

While the spermatogenesis has been worked out in a few species, no nucleus has been found in the adult sperms, and there is strong evidence that the sperms are now functionless.

The sperms have been filmed under varying powers of the microscope and the nature of the movement examined.

The survival of these functionless sperms, and especially the survival of a very long spermathecal duct in genera and species in which males have long ceased to occur, presents an interesting problem from a genetical point of view. It is hoped that this point will be discussed.

Dr. H. Sandon.—*Pseudopodial structure and movements in Foraminifera* (12.30).

The pseudopodia of Foraminifera have been studied from three points of view: (1) In relation to the life processes (especially feeding and locomotion) of the Foraminifera themselves, (2) in connection with the interrelationships of the different orders of Rhizopoda (the separation of which is based largely on pseudopodial form), and (3) in connection with more general problems of protoplasmic structure and movement.

Commonly even the finest pseudopodial thread contains two oppositely moving streams of granules, the velocities of which are independent of the thickness of the thread. A relatively tough moving ' skin ' is also present on whose properties depends the selection (i.e. adhesion or non-adhesion) of food and other foreign objects. The exact location of the other moving parts and the existence of an axial rod are more doubtful. The protoplasmic movements are independent of the existence of a free pseudopodial tip or of contact of the pseudopodium with a substratum, and are therefore not dependent on any gradient in surface tension, etc. Analogy with the known structure of an amœban pseudopodium is of only very limited application. Some preliminary experiments on the effects of chemical and other stimuli seem to open up a promising method of studying the physical conditions which confer the necessary stability on these fine fluid threads.

Afternoon.

Prof. W. C. O. Hill.—*The affinities of the Lorisoids* (2.15).

Definition of the Lorisoids to include Slender and Slow Lorises, Galagos and Pottos. Characters which all these have in common. Characters in which they resemble the Lemuroids. Characters in common with Tarsioids. General status therefore intermediate. Position of *Cheirogaleus*. Relation of *Loris* to the remaining Lorisoids and to *Tarsius*. General appearance

and mode of life. Specialised characters. Primitive characters. Geographical and geological factors. Inferences. Own views on the classification of the Primates arising from above study.

Mr. D. R. R. Burt.—*The correlation between climatic factors and the distribution of the geographical races of some Ceylon mammals* (2.45).

The different factors, temperature, relative humidity, light, altitude, etc., which constitute the climate in different regions of Ceylon are discussed. On the basis of these factors the Island is divided into three distinct zones: low-country dry zone, low-country wet zone, and the central hill zone which is also wet. The geographical races of different mammalian species are considered and their morphological differences are correlated to the different climatic factors.

There is a relation between external temperature and the internal temperature of an animal, its metabolic rate, its body size, and the ratio of the length of its appendages to the length of its body. The differences in the morphological characters of different geographical races are attributed to the efficiency of the temperature-regulating mechanism of the organism under different climatic conditions. Humidity, light and altitude modify the effect of external temperature on the body, the greatest effect being that of humidity, which accentuates the effect of temperature, preventing heat-loss when the external temperature is high and the main process of the heat-regulating system is heat-loss, and increasing heat-loss when the external temperature is low.

Prof. G. D. Hale Carpenter.—*Protective colouration in insects with special reference to mimicry* (3.15).

Saturday, September 8.

Excursion to Upper Donside.

Sunday, September 9.

Visit to the Fishery Board for Scotland's Research S.S. *Explorer.*

Monday, September 10.

Joint Symposium with Section K (Botany) on *Biological problems of fresh water* (10.0):—

Prof. F. E. Fritsch, F.R.S.—*The origins of plankton.*

Dr. W. H. Pearsall.—*The causes of algal abundance.*

Algal abundance under natural conditions appears to be primarily related to the oxidation of organic matter in the water, and, indirectly, to floods which may increase the supply of products of oxidation. Examples from streams, lakes and laboratory cultures suggest, however, that algal abundance does not only depend on the presence of an adequate supply of certain dissolved salts. It appears also to depend upon the balance between certain nutritive materials such as, for example, the ratio between the concentrations of nitrates and phosphates or between the nitrogen supply

and carbohydrate production. The anomaly apparently exists that a water may have adequate supplies of nutritive salts and yet a comparatively small algal flora.

Mr. J. T. Saunders.—*Temperature observations and water movements in lakes.*

Mr. F. T. K. Pentelow.—*The food of some freshwater fishes.*

Dr. B. Barnes.—*The biology of aquatic fungi.*

Freshwater fungi belong chiefly to the Archimycetes and Oomycetes; species of Zygomycetes and of Ascomycetes are few, and Basidiomycetes seem to be unrepresented.

Our knowledge of the biology of aquatic fungi is scanty, based on incidental observations. No one seems to have studied the fungal population of a piece of water over a period of years.

The Archimycetes are mostly parasites, attacking other fungi, algæ and animals. Some are saprophytes, and it is possible that the virulence of the parasitic species has been over-stressed. The Oomycetes are mostly saprophytes, some having a remarkable tolerance of bacterial associates. Oomycetes appear to be most abundant in the colder parts of the year, but since vegetable debris gathered in summer has yielded good fungal growth after a few days at low temperatures, it seems likely that some mycelium persists throughout the year.

So far as can be judged, fungi are not normally prominent members of the aquatic population. As, however, they grow and multiply rapidly, special conditions may induce mass occurrence, such as is well known in *Leptomitus* in contaminated water.

Afternoon.

Discussion on *The inheritance of productivity* (2.15):—

Mr. John Hammond.—*Meat.*

Introduction.—Almost all the characters of any importance for meat are dependent for their full expression on nutrition. The mutations which occur are nearly all recessive and consist of defects or fancy points. Commercial qualities are formed by the accumulation of small variations developed in response to the environment, and exist in varying degrees of fixity. Evolution of the gene has to be considered as well as mutation of the gene. These principles are illustrated by the evolution of the horse and by reciprocal Shire-Shetland crosses.

Cattle (beef and veal).—Selection for beef conformation is only effective under nutritional conditions which develop the characters. The directive influence of man's selection is shown by a comparison of age changes in the conformation of breeds of different origin bred for the same purpose. Large mutations (Doppellender calves for veal) play no part in the evolution of beef cattle. Body fat colour requires a definite environment of food supply before selection can be made for the genetic factors concerned.

Sheep (mutton and lamb).—The proportions of bone, muscle and fat in different breeds and crosses are developmental characters which depend on nutrition. Crosses between these ' developed ' types of different levels give intermediates which do not segregate sharply as do those of a mutation (Ancon sheep).

Pigs (bacon, pork and lard).—Local feed conditions have supplied the

environment in which the different types have been developed. Maize has developed the lard type in Hungary and America ; skim milk and cereals the bacon type in Denmark ; and skim milk and meat meal the pork type in New Zealand.

Conclusions.—Since the genetic characters concerned are so dependent for their expression on nutrition, and are mostly of a ' developmental ' character, the best means of directive improvement is selection (by progeny tests) in an environment which stimulates the development of the character in question. The further development of these commercial qualities in our animal depends, like ' civilisation qualities ' in man, on the creation of a better environment for the development of the characters concerned.

Mr. A. D. Buchanan Smith.—*Milk.*

It is presumed that the purpose of this discussion is to determine whether the science of genetics can offer reasonable help to the livestock producer. If so, then by what means ?

Genetical experiment in respect of milk is easier than in the case of meat, since the former is more amenable to measurement, both of quantity and quality. As regards milk, there are two main difficulties. The first is to discriminate between those factors which affect the productivity of the animal and are not of genetic origin. The difficulty of doing so is one of the rocks upon which many experiments have foundered. To overcome this, the method now being adopted in the United States and at Edinburgh is to maintain a herd of dairy cattle under a uniform system of management over as long a period of years as possible. Thus, although the production of one generation takes place years after the production of the ancestral generation with which it is to be compared, the comparison may be considered to be reasonably straightforward.

Actually the science is not so much concerned with the determination of the number of genetic factors involved, but rather with an analysis of the lactation curve of individual animals under standard environment. (Animals giving similar yields may do so in spite of different genetic constitutions.) It is of fundamental importance to understand the action and reaction with each other of the various characters and components of milk. Deliberate research of this nature will discover whether abnormal modes of inheritance are operating, such as sex linkage and combinations of genes which act as inhibitors of yield. The possibility that economic production may actually be best obtained when genes are in a heterozygous state is discussed, as also whether certain combinations of characters, desirable from the standpoint of the practical breeder, are genetically possible.

The principal difficulty of the disentanglement of genetic factors can now be overcome by means of the experimental herd with controlled environment. This leads to the next difficulty, that the analysis may reveal so many genetic factors interacting with each other as to make the synthesis of the problem almost an impossibility as regards practical application.

Simple selection is discussed, and the work of Winter with maize is quoted, as well as the observations of ' Student ' and Fisher. Owing to the immense amount of time involved, a similar improvement in productivity cannot be expected in our dairy cattle. Selection has great value on unimproved stock, but as the quality rises, the rate of improvement decreases rapidly. The ' progeny test ' is discussed as the logical refinement of existing methods of selection. The conclusion is drawn that without fundamental knowledge the rate of improvement is bound to get slower.

The demands of the market are not stable. Without fundamental knowledge concerning the inheritance of the various characteristics of the lactation it will not be possible to keep pace with market fluctuations by simple selection with, or without, the progeny test.

Finally, productivity depends on close interrelation of control of disease with nutrition and genetics. Improved methods of feeding put new stresses on the machine, which can only be made by the adjustment of the hereditary constitutions of the animals. Experiments conducted by the writer with pigs are quoted to show how it is possible for the interior economy of an animal to be modified to suit nutritional requirements.

Dr. A. W. Greenwood.—*Eggs.*

(1) Selection methods practised along the right lines tend to increase productivity particularly in unimproved stock, but progress is slow in improved stocks because of the inability of the breeder to control heredity.

(2) It has been shown that the desirable qualities to select for are inherited and their mode of transmission from parent to offspring determined.

(3) Such knowledge need not necessarily affect selective breeding practice because of the present inability to distinguish between hetero- and homozygous forms of these genes.

(4) The application of genetical knowledge to breeding requires either a method of distinguishing these forms by their production records, or else an accessible technique whereby the genetical constitution of an animal may be accurately determined. With this knowledge at his disposal, the fixation of desirable characters in a flock can be easily made.

(5) The field of work of the geneticist covers not only the mode of transmission of characters under optimum conditions but also the effect of variations in the environment on the resultant expression of gene action. For this it is essential to deal with animals of known genetic constitution.

(6) The final phase in the genetical analysis concerns the relation between the gene and the mechanism by which the end result—the character—is produced. The possibility of the control of heredity through the control of physiological processes is foreshadowed.

Dr. J. E. Nichols.—*Wool.*

The interrelations of the fleece attributes differ according to breed, to locality, etc. The fleece has to be an adequate covering for the sheep and also a saleable product. The wool fibres have usually been considered in genetic studies, being the most amenable to analysis among the several products of skin metabolism which make up the raw fleece. Studies on fineness, length, etc., tend to show that multiple factors are involved, but environmental effects are so profound that recognition of the optimal states of the various fleece characters, in relation to biological or economic conditions, is important.

In practice, cases are frequently found of selection being most readily achieved in specific environments. These are discussed, and attention is called to the importance of studying the circumstances which favour selection of productive capacities in respect of the main fleece characters.

Dr. J. L. Lush.

Visit to Marine Laboratory of the Fishery Board for Scotland and to the Research Station of the Department of Scientific and Industrial Research, Torry.

Tuesday, September 11.

Joint Discussion with Section J (Psychology) on *The interpretation of animal behaviour* (*Section D room*, 10.0) :—

Prof. J. A. Bierens de Haan.

The interpretation of animal behaviour forms the foundation of animal psychology, and is of fundamental importance for it, as it is decisive for one's attitude towards this science, and may even lead one to reject it as impossible. There are three main tendencies with regard to this interpretation : (*a*) the physiological or analytical one, which attempts to analyse the actions of animals into as complete a number of reflexes as possible. This is not very satisfactory, as it gives us only a number of parts, while the bond that links them is lacking, and it would also give a very unsatisfactory interpretation of our own behaviour. (*b*) The synthetical interpretation, in which we may again distinguish two tendencies : firstly, a tendency for interpretation only in terms of objectively perceptible phenomena (stimulus and response), and, secondly, one in which are taken into account subjective or psychical phenomena. If the latter is possible with animals, it will satisfy us better than the other, as we know in our own case that an interpretation that does not take such phenomena into account neglects some fundamental elements that govern our behaviour. Therefore we will accept the objective interpretation only when the other one is proved to be impossible. That may be the case : (i) when subjective phenomena do not occur in animals, or (ii) when they do occur, but are not recognisable by us. To settle the first point the seven marks of behaviour of MacDougall are used as a criterion. Testing the activities of animals by means of these seven marks, it may be shown that even in the Protozoa real ' behaviour ' as an expression of subjective phenomena exists. As to the question whether these subjective phenomena are sufficiently knowable it is argued that everybody, even the behaviorist, uses them in the practical interpretation of the behaviour of animals, so that it would be inconsistent not to do it in the laboratory. The objection that with the lower animals the analogies between their attitudes and our own diminish, so that with them the difficulty becomes greater, is rejected with the remark that we do not interpret the behaviour in subjective phenomena by observing these attitudes, but by imagining ourselves to be the animal, by a ' transferred introspection,' and by the result of special experiments directed to special questions (discrimination, understanding, etc.). So we are fully within our right in interpreting the behaviour of animals in terms of subjective phenomena.

Another question is : *Why* do we want to interpret the behaviour of animals ? It might be done for practical reasons, or for a better understanding of our own nature. Yet the chief value of our interpretation of animal behaviour lies in the fact that it brings the material for the science of animal psychology, that has as its object those subjective phenomena, and as its aim the knowledge of their psychical constitutions. Further : the interpretation of the behaviour of animals and the building up of this science of animal psychology, although both psychologists and biologists may work together, must for the greater part be done by biologists, as the interest of the psychologist will be confined to the higher animals, where some resemblance to the human mind may be expected, while for the biologist all animals have equal rights as subjects of his study. Therefore the interest of biologists must be awakened in the study of this aspect of animal life.

Dr. S. Zuckerman.

Mr. Rex Knight.

Two questions are frequently confused: (i) What mental experiences do animals possess? (ii) What are the causes of animal actions? These questions are distinct, for it is possible that animals do have mental experiences and yet that these experiences do not affect their actions. A similar theory is widely held even with regard to human beings.

In considering the first question, it seems plausible, by analogy from ourselves, to ascribe mental processes to some animals; but the precariousness of the inference is shown by two facts. First, many animal actions, which, considered in isolation, seem to indicate rational foresight, turn out, on examination of their context, to be instances of instinct or acquired habit; secondly, decerebrate and spinal preparations can perform many actions which, when performed by normal animals, are frequently taken as evidence of mental activity.

The second question—What are the causes of animal actions?—can be more definitely answered. By controlled observation we can examine separately the antecedents of any particular action, and so discover which of them are severally necessary and jointly sufficient to produce the action. Scientific inquiries of this kind afford no justification for the view that some animal actions cannot be the effects of non-mental causes.

Prof. W. McDougall, F.R.S.

Dr. H. O. Bull.

Dr. F. Darling.

Observational work is being carried out upon a herd of Scottish Red Deer, which species is a particularly suitable subject for such work because it is a large animal living above ground, it is extremely sensitive to changes in environment, it has a well-developed community life, and a year forms a definite unit of time in its social life.

Work upon such a species is likely to be fruitful in interpreting certain lines of animal behaviour, (*a*) because animals in the wild state seem to react differently on different occasions to similar sets of circumstances, which must mean that there are variables present of which we are, as yet, unaware; (*b*) because laboratory experiments on animal behaviour as pointers towards interpretation should only be conducted after a considerable knowledge has been gained of the animal's behaviour in freedom; and (*c*) because, as most animals are in some measure gregarious, their behaviour as individuals and as members of a group cannot be divorced, and there is much to be learnt about community life of which the individual life is only a part. Among the many aspects of the deer's life observed are the three territorial seasons and their sharply differentiated characteristics, meteorological factors, biological factors, relation of the sexes to one another and the different behaviour of the sexes in the social structure of the community during the different seasons of the year.

Afternoon.

Discussion on *The currents of the sea and their biological importance* (2.15):—

Dr. J. B. Tait.

The sea itself constitutes the environment of marine life, and the study of this relationship is one of the chief purposes underlying the collection of

physical and chemical data pertaining to sea water *in situ*. The most fundamental property of the sea is its constant and more or less complex motion, to which all questions concerning the sea itself, or its inhabitants, must sooner or later be referred.

Horizontal movements, or currents, particularly those in the upper sea layers, are the most obvious and, generally speaking, are of the first importance from a biological point of view. Their measurement in the northern North Sea by the drift-bottle method has produced some striking results, both in regard to direction and velocity. These results have proved of value in the interpretation of adolescent and adult fish migrations in this region. Biologically they are significant also from the standpoint of plankton and young fish movements.

Dr. J. N. CARRUTHERS.—*Certain fishery applications of the results of researches on marine currents carried out from the Lowestoft Fisheries Laboratory.*

An account was given of continuous current measuring observations carried out from the *Varne* lightship in Dover Straits. From this moored vessel a current-meter has been employed for eight years, and data regarding the water exchange between English Channel and North Sea have been amassed over that period. The varying water movements there observed, when balanced out over a term of years, have effected the same overall transport of water as would have been accomplished by a very slow river flowing at the rate of about $3\frac{1}{5}$ miles a day from the English Channel to the North Sea. Under certain circumstances the current flows the other way. Following winds quicken it and head winds impede it. A play of such wind conditions over the North Sea at large as would be expected to pool up the Southern Bight (and north-westerly wind conditions are well known to do this) can most effectively hold up and reverse the current.

The results of the last three years are of especial interest, for, instead of the residual current heading boldly into the North Sea (as it most frequently had done in the previous three years) it has displayed less and less easting with the passage of time. During 1933 the current headed about half a point west of north.

Such long-enduring modifications of the current are held to be analogous in a way to the short-lived modifications produced by wind influence. The inferred cause in their case, however, is an oceanic pulse—an accession of strength on the part of the parent supply stream which flows in from the ocean round the north of Scotland. This causes an extra strong southward urge of waters through the North Sea—with the results observed in 1933 particularly.

The Dover Straits current attains its strongest and weakest rates of flow half a year later than does the current entering the North Sea round the north of Scotland, but a quarter-year later than the current in the Cromer Knoll region.

These facts are interpreted to indicate that the Dover Straits current waxes and wanes through the year in a sort of buffer relationship with the current from the north—that there exists a sort of see-saw conflict between the two.

The vagaries of the Dover Straits currents, on the strength of the findings mentioned, are held to serve as pointers to major modifications of the currents in the northern and middle reaches of the North Sea half a year earlier.

The results obtained from the current measurements in question have been applied to various problems of fishery interest. Among problems of

immediate local concern (i.e. germane to the southern North Sea) there are the questions of good and bad survival years for the plaice and for the herring of the great East Anglian Autumn Fishery. The latter originate from vast annual spawnings in the eastern end of the Channel. It seems that good fortune has attended the broods of both fish when, during the egg and/or fry stages, the current issuing from Dover Straits has been most average in point both of strength and direction. This accords with the supposition that good augury for a plaice brood exists when the products of the spawning are transported to the continental coastal shallows—the so-called young plaice nursery grounds.

Other problems calling for the application of the *Varne* light-vessel current data in their local role are concerned with the intermingling of two types of herring through the straits, and with the outcome of the Belgian Spent Herring Fishery. This latter is carried out upon fish supposedly enfeebled by the operation of spawning in the eastern Channel.

Applied at a distance as it were, on the strength of the facts set out above, the Dover Straits current data enable something to be said about good and poor haddock years. The haddock fluctuates very closely (though oppositely) with the herring, and seems, when in the egg and fry stage, to have experienced the best survival conditions when we should judge the waters to have been most strongly urged towards the south.

The year-class fluctuations of the cod have been studied side by side with meteorological data, and it appears that the best augury for a brood obtains in those spawning seasons during which winds from the half-compass centred on N.E. have been at a maximum—a finding which accords well with what was inferred in the case of the haddock from the *Varne* current data.

Prof. A. C. Hardy.

Mr. E. R. Gunther.

Two comparisons are chosen to illustrate the importance of *vertical* currents to biology. The first between the Labrador Current, which flows over the rich fishing-grounds of the Newfoundland Banks, and the Falkland Current, which flows over the less rich grounds of the Patagonian Shelf. These two are analogous currents, since they are both regarded as compensating for the eastward deflections of the Gulf Stream and of the Brazil Current. But they are not homologous, since the Labrador Current has an arctic origin and is consequently rich in nutrient salts which are brought to the surface through the agency of vertical currents induced by melting ice; and the Falkland Current, having its origin in the water of the West Wind Drift, is not of antarctic origin and consequently is less rich in nutrient salts.

The second comparison is between the oceanography of the Patagonian Shelf on the East Coast of South America and that of the Humboldt or Peru Current on the West Coast. Conditions on the Patagonian Shelf are such that the Falkland Current *converges* with the coast and the water circulates in a more or less closed system, and consequently there is a limited tendency towards upwelling. On the West Coast, on the other hand, the work of the Royal Research Ship *William Scoresby* has demonstrated the presence of a *divergence line* along the coast whereby upwelling of cool water rich in nutrient salts from the lower layers is induced. To this is attributed the outstanding richness in the marine fauna for which the West Coast is notorious.

Correlations are given between southerly and easterly winds and the divergence from the coast of the surface water leading to the upwelling of cool water ; the subsidence of the latter upon a failure or a change of wind. Correlations are also given between the plankton and the nutrient salts, and between the phytoplankton and the zooplankton and the animals of economic importance.

SECTION E.—GEOGRAPHY.

Thursday, September 6.

PRESIDENTIAL ADDRESS by Prof. A. G. OGILVIE, O.B.E., on *Co-operative research in geography ; with an African example* (10.0). (See p. 99.)

Lt.-Col. A. B. CLOUGH, O.B.E., M.C.—*The geographical considerations in the delimitation of international boundaries* (*with special reference to the Northern Rhodesia-Belgian Congo Boundary*) (11.15).

Boundary 'delimitation' is the work of the political administrator, 'demarcation' that of the commissioner and surveyor. Necessity for basing treaty decisions on trustworthy facts and geographical knowledge. Difficulties in past due to lack of geographical knowledge on part of treaty makers. Various sorts of national and artificial boundaries—e.g. rivers, watersheds, mountain ranges, meridians, parallels, etc. ; their virtues and failings, and some classical examples.

History of boundaries in Central Africa. The partitioning of Africa among European powers. General geographical and climatic characteristics in Northern Rhodesia. Treaty definition of boundary between Northern Rhodesia and Belgian Congo dividing the boundary into five main sections.

First demarcation by Commission in 1911–14, and what they accomplished. Post-war mineral development and its repercussions. Necessity for more intensive boundary demarcation.

New Commission commenced work 1927 along the watershed section. Necessity for re-triangulation : its execution, and difficulties due to climatic and topographical causes. Location of watershed, erection of beacons and boundary traverses.

Geographical considerations affecting the Mpanta meridian, River Luapula and Lake Mweru sections. Point of doubt and discussions regarding the straight-line section between Lakes Mweru and Tanganyika. Necessity for remapping this section. Establishment of co-ordinates of boundary pillars : drawing up of plans and keeping open the boundary cutting. Encroachments over the boundary and their adjustment.

Mr. J. MCFARLANE.—*The basins of the Dee and the Don* (12.0).

Mr. J. S. THOMS.—*The northern valleys of Angus* (12.30).

The transverse, immature and intensely glaciated valleys of northern Angus, deeply cut in the gently rolling surface of the Grampian peneplain, and separated from each other by a series of tapering, asymmetrical spurs, carry excellent pastures on their drift-covered slopes, while the natural vegetation is peculiarly suited to game. In spite of climatic uncertainty

and danger from flooding, the elevated valley floor areas of alluvial accumulation carry a modification of the large-scale mixed farming of Strathmore, founded on security of land tenure, suitable rotations, sound drainage method, and easy access to markets. Small-holdings are few, and farms generally exceed 300 acres. Cereal cultivation is confined to the alluvium, and oats, the dominant crop, is grown to an elevation of 850 ft. Agricultural vicissitudes of the last decade have been responsible for a marked increase in head of stock, sheep having increased by 50,000. Inability to grow barley economically has been responsible for a two-thirds decrease in the area under that crop. The oats, turnips, and potatoes acreage has remained steady, while permanent grass has shown a substantial increase. Development of stock-raising at the expense of arable agriculture has led to recent depopulation, the people having moved from the valleys to the Highland margin farming districts. Nevertheless, the present density, 9 per square mile, is high for an upland area.

The etymology alone bears evidence of former Celtic influence in this region. The present population is of well-mixed origin, and is largely derived from capable Strathmore farming stock introduced when this area was under ecclesiastical jurisdiction, and later.

AFTERNOON.

Excursion around Aberdeen.

Friday, September 7.

Lord Provost HENRY ALEXANDER.—*The Aberdeen planning scheme* (9.45).

The Aberdeen and District Joint Town Planning Scheme, which received the final approval of the Department of Health for Scotland on March 17, 1933, and which has therefore been in operation for a year and a half, covers an area of 96·96 square miles and is the largest scheme of the kind so far carried out in Scotland. It comprises land lying within the city of Aberdeen and within the adjoining counties of Aberdeenshire and Kincardineshire, and it was prepared by a Joint Committee set up with statutory powers under the Town Planning (Scotland) Act, 1925. This committee, which began work in 1928, acted throughout in close consultation with all interested parties, and, thanks to the enlightened support of the landowners of the region, it was able to carry its proposals with comparatively few modifications. The scheme includes a complete system of radial and ring roads, zoning and density provisions, and ample reservations of land for recreational and amenity purposes. In particular, the landscape features of the sea-coast and river valleys have been safeguarded. Similarly, the economic interests of the region have been secured by the reservation of industrial areas.

Mr. J. CRUICKSHANK.—*The Aberdeen Joint Town-Planning Scheme: landward section* (10.25).

The region round the city of Aberdeen lends itself admirably to the purposes of town planning, for it is favoured by natural assets which are but rarely found.

In the first place the area takes the form of a horse-shoe with a chain of hills which form a natural outer border or rim. In the second place there is the sea-coast, with sandy beaches or bold cliffs. Lastly, there are its two rivers, the Dee and Don, and their lower tributaries.

The horse-shoe or fan-shaped formation lends itself readily to a series of ring roads. These ring roads would afford shorter distances for traffic and they would relieve the congestion in overcrowded streets in or near the city, while they would help internal development along their routes.

In regard to zoning, and to the number of dwelling-houses per acre, certain districts have been placed as low as two to the acre (where this is the number that these districts have already set for themselves), while eight to the acre may be taken as a fair average. The number may rise to sixteen and even as high as twenty-four in industrial areas.

Open spaces have been carefully studied and are expected to keep pace with the progress of building developments. Where a landowner sets aside part of an area for an open space he may build on the remainder at a correspondingly greater rate of density in the number of houses.

Amenity has been kept in view by listing objects of historic interest or of unusual scenic value or archæological note. Experience already gained goes to show that the communities concerned stand to gain materially by the operations of town planning.

Discussion on *Planning* (11.0).

Dr. CATHERINE P. SNODGRASS.—*Agricultural distributions in Aberdeenshire and Kincardine* (11.40).

The contrast between the agriculture of the lowlands north and south of the Highland boundary is illustrated. In southern Kincardine the farming system resembles that of the rest of Strathmore, the emphasis being on cash-cropping (grain and potatoes) with associated cattle-feeding and subsidiary stock rearing. In Aberdeenshire and northern Kincardine the main concern is cattle rearing and feeding, and the most characteristic feature of the agricultural distributions is their uniformity, the sharp contrasts which occur in many parts of Scotland with variations in physical conditions being, with few exceptions, absent. This uniformity can be attributed (1) to the physical conditions which set limits to the possible variations from the prevailing type ; (2) to the distance from large centres of population, which practically confines dairying and commercial potato production to the Aberdeen neighbourhood ; and (3) to the great influence of tradition. The crops best suited to this region can only be effectively marketed by adopting some form of stock farming, and the existing system, with its overwhelming emphasis on beef production, subsidiary pig and poultry rearing and almost complete exclusion of sheep (a feature rapidly altering during the present decade), has gradually evolved in response to changing economic conditions.

Major M. HOTINE.—*National maps as backgrounds* (12.0).[1]

Consideration of the work of the early geographers and surveyors. Value of a map as providing an environment or landscape for demonstration and explanation of many subjects of interest. Advantages of illustration by map over mere statistical tabulation.

Early Ordnance Survey maps were on copper. Everything to be shown had to be engraved and incorporated on the map itself. Photo-mechanical process of map reproduction, its genesis, and how it made possible the use of overprints for showing special information. Collection of information by Directors-General of the Survey, with special reference to details of

[1] Read by Mr. S. J. K. Baker.

archæological and historical importance. Growing tendency for men of history and science to show distribution and evidence upon maps: increase of knowledge and growing interest of general public in scientific and historical subjects demands more room and clearer illustration; hence gradual development from using very small scale maps or sketches in periodicals and professional papers to the use of larger scale national maps for the purpose.

The national cartographic institutes well equipped for such work. All necessary material available in many forms and cartographic experience available to ensure best use of material. These institutions have advantage also of getting in touch with colleagues of other nations if the theme be international. How the Ordnance Survey organises research into and collection of old plans, maps and other such material. Research into the past through the medium of air photography.

Examples of national maps as backgrounds: Physical Map of Great Britain (1/M); Land Utilisation (1-in.); Population (1/M); Neolithic Wessex (½-in.); Roman Britain (1/M); Celtic Fields (1/25,000).

Afternoon.

Mr. W. Smith.—*A preliminary study of the rainfall of China* (2.0).

The paper is an analysis of the rainfall data, in the form of 35-year averages and corrected to a 30-day month, for some eighteen stations. These are distributed along the China Coast and the Yang-tze Valley, and they provide a framework of 'normals' to which the short period data in the interstices will later be related. The 35-year period taken, 1895 to 1929, is shown to be one complete rainfall cycle.

Certain rainfall provinces are distinguished and their seasonal distribution of rainfall analysed. The rainfall seasons distinguished are three:

1. A winter monsoon from October to February or March. Rains are scanty in North China (½ in. per month) but not inconsiderable elsewhere, and greatest in the lower Yang-tze Valley (2 in. per month).
2. A pre-summer monsoon season from March or April until the beginning of the summer monsoon (June in the Yang-tze Valley and South China, July in North China). Rains are still low in North China (1 in. per month), but elsewhere considerable (4 in. per month and over), increasing rapidly in April and May.
3. A summer monsoon from June or July to September. The front of the monsoon is usually the period of maximum precipitation, and the rains fall away month by month from this peak. Along the South China Coast, however, they increase again in August and September.

In conclusion an attempt is made to relate the results of this analysis to the atmospheric circulation of the Far East, and to construct a rationale of the rainfall seasons distinguished.

Mr. P. R. Crowe.—*Rainfall probability, with special reference to the High Plains region of U.S.A.* (2.30).

The traditional method of summarising monthly rainfall data has been by means of the arithmetic average, and the recent history of geography points to increasing dependence upon data arrived at in this fashion. The fundamental faults of this system are: (1) that the average is influenced too greatly by occasional very high records, (2) that the inherent variability of rainfall is obscured, and (3) that hence we have no indication of the range within which differences between averages must be regarded as insignificant or fortuitous.

A new method is outlined which obviates these difficulties by utilising median and quartile values. Since mathematical proof of its assumptions is not easy, it is applied experimentally to a large continental area along a zone of climatic transition. The High Plains and the neighbouring Rocky Mountain Piedmont are thus found to fall into five clearly defined rainfall regions :

(1) The *Southern Type* with the major rainfall season between April and October inclusive, e.g. Dodge City.

(2) The *Central Region* with rains increasing in April still, but declining rapidly in September, e.g. North Platte.

(3) The *Northern Region* with May and June as the only two really rainy months, e.g. Miles City.

(4) The *Laramie Region* with light spring rains decreasing rapidly in June, e.g. Denver.

(5) The *New Mexico Region* with late summer rains bursting abruptly in July, e.g. Santa Fé.

The two latter regions thus differ widely from each other, and the contrast between Denver and Colorado Springs is very marked despite the absence of physical barriers. The only feature common to the far west is the low rainfall expectation for June. The extension of this feature eastwards towards the Plains proper produces a transitional zone within which drought is often very serious. Other transitions towards the western deserts and the humid east are also observable in some of the 73 charts studied, but the major regions are clear and logical in outline.

Some correlations with crop belts are observable, yet the regions outlined are capable of both definition and subdivision on the basis of criteria yielded by precipitation data alone.

Discussion on previous communications (3.0).

Prof. E. G. R. Taylor.—*Perfidious Albion : climate and character in the sixteenth and seventeenth centuries* (3.15).

The attitude of the average educated man towards racial character in this period is summarised in a poem translated from the French in 1603, when a Scottish succeeded a Tudor monarch :

> ' O see ! How full of wonders strange is Nature !
> Sith in each Climate, not alone in Stature,
> Strength, colour, hair, but that men differ do
> Both in their Humours and their Manners too.
> The Northern man is fair, the Southern foul ;
> That's white, this black, that smiles and this doth scowl.
> Th'one's blithe and frolick, th'other dull and froward,
> Th'one's full of courage, th'other a fearful coward ! '

Dr. H. C. Darby.—*Some ideas of climate and weather in the later Middle Ages* (3.45).

From A.D. 1100 on to the close of the Middle Ages, contemporary ideas upon meteorology and climatology were drawn from three sources : (1) Traditional scholarship, the foundations of which had been laid in the works of Pliny, Solinus and St. Isidore of Seville. (2) Those Arabic texts which were now becoming known to the West and which, in turn, were revealing the scientific treatises of Aristotle. (3) Direct observation of

storms and other natural phenomena, which were being recorded and noted by chroniclers and travellers.

Prominent among the thinkers of the time were William of Conches, Robert Grosseteste and Gervase of Tilbury. They, and others with them, dealt not only with the elements of meteorology (wind, temperature and precipitation), but also with the climatic differences (both zonal and topographical) that were reported to exist upon the surface of the globe. Nor did some writers neglect the influence of climate upon man. In estimating their achievements in this branch of science two facts have to be remembered : (*a*) that the men of the Middle Ages were essentially country folk, and (*b*) that they may have reasoned within limited premises, but it cannot be denied that they reasoned well.

Discussion on previous communications (4.15).

Saturday, September 8.

Excursion to Tarvis, Inverurie, Alford, Kildrummy, Loch Kinord, Aboyne, Coull, Slack and Loch Skene.

Sunday, September 9.

Excursion to Inverurie, Kildrummy, Dinnet, Burn o' Vat, Banchory.

Monday, September 10.

Prof. W. W. Jervis.—*Social geography of Greenland* (10.0).

Greenland provides an excellent field for the study of social geography. It is unique in that the contacts between the Eskimos and white peoples have in the main been carefully controlled and the development of certain changes can, therefore, be studied systematically. The results of the introduction of new materials and new weapons are obvious. Light calico and canvas tents, easily packed and light to carry, are being introduced at the expense of the native skin tents, despite their greater inability to keep out rain and to keep in heat. The importation of wood is reflected in the building of wooden houses on Danish models to replace native huts. Rifles and shot-guns are being increasingly used, sometimes with disastrous results. The former are found more in North Greenland than in South Greenland, where the harpoon remains the partner of the kayak and where the shot-gun is adapted for bird shooting. This, however, is fortunately not the whole story in Greenland. Since the later part of the eighteenth century, relief has always been granted to natives in economic distress. Since the middle of the nineteenth century, the Danish Government has adopted the policy of paying the Eskimo a fixed price for his products. From the money obtained from the sale of Greenland products in European markets, a sum equivalent to one-fifth of what the native has already been paid for his products is set aside and applied to ' the development of native culture and the uplifting of their condition.' Some of this is distributed to the Kommuneraad and to the Sysselraad, and grants can be made for educational and medical services. Further, relief can be granted. Thus if a hunter is forced in an emergency to eat his dogs, he can be compensated. Again, a bonus can be declared, and the administration of this bonus has certain geographical implications which are discussed in the paper.

Organisation of this kind is developing a sense of personal possessions and is tending to group the people in larger settlements. These and other results are briefly discussed.

Prof. F. DEBENHAM.—*An Eskimo kayak voyage to Aberdeen* (10.30).

In the late seventeenth and early eighteenth centuries there were several occasions on which Eskimo in kayaks were observed by the islanders off the Orkneys. In one case, an Eskimo reached Aberdeen, where he was either driven ashore or captured at sea. He died after a few days, and his kayak and hunting equipment are now in the Museum in the Department of Anatomy at Marischal College.

The evidence for these voyages is analysed and the route and methods employed in making the voyages are suggested. The evidence is too slight to allow of more than a vague suggestion as to the reasons for Eskimo coming to the East in this way.

The seaworthiness of the kayak is an important point in the evidence, and this is illustrated by films of Eskimo and Englishmen using the kayak both in East Greenland and on an English river.

Discussion on previous communications (11.0).

Dr. ELSPET W. MILNE.—*Irrigation in Norway* (11.20).

The mountains and glaciers of the Jostedal, Jotunheim and Hardanger groups cause precipitation from the moisture-bearing westerly winds, so that a marked rain-shadow area covers the valleys of Upper Gudbrandsdalen and Inner Sognefiord. Within this area the period March to mid-July has very low precipitation, whilst summer temperatures are high in the valleys, owing to their depth, narrowness and rocky walls, so that evaporation is great. On the lighter and more porous soils, especially where these occur on steep slopes, crops cannot be grown without irrigation. In the eastern part of the area the farmland lies above the larger streams, and water must be led from plateau streams and glaciers by long, carefully adjusted canals. In the western part of the area sources are more accessible, but the farmland is so flat as to introduce difficulties. Distribution is by a network of small canals and runnels, adjusted to the slope, soil and crop of the fields to be irrigated, and a technique of irrigation designed to minimise the risk of soil erosion has been developed.

Irrigation is normally stopped in July, but in regions with very unfavourable conditions of soil and climate it is continued throughout the growing season.

Mr. S. J. K. BAKER.—*The social geography of Western Uganda* (11.40).

The western highlands of Uganda present a complex environment which has in the past proved attractive both to the cultivator and to the pastoralist. Apart from the numerically negligible pygmy people there are two main elements in the population of this region. In the first instance a Bantu population established itself in the land and its members gained their livelihood mainly by the cultivation of the soil. More recently a strongly 'Hamitic' element has entered and, with a different regional experience behind it, has seized upon the pastoral potentialities of the extensive grasslands. The pastoralists appear to have been accepted as overlords by the earlier inhabitants, and there has thus arisen an order of society in which a Bantu peasantry is dominated by a pastoralist aristocracy.

In Ankole physical conditions have allowed the incomers to maintain their old way of life unimpaired, and the two elements have, to their mutual detriment, remained racially and socially distinct. Farther north, in Toro and Bunyoro, with a physical character less favourable to the pastoral mode of life, the invaders have been unable so completely to preserve their identity, and a greater degree of fusion between the two elements has taken place. It is of some significance in this connection to notice that the kingdom of Bunyoro has achieved a higher order of social and political cohesion than its neighbour Ankole, though the achievements of Buganda have not been equalled in any of the western kingdoms.

Mr. W. Fogg.—*Villages and suqs in the High Atlas mountains of Morocco* (12.10).

Discussion on previous communications (12.30).

Afternoon.

Mr. J. N. L. Baker.—*Distribution of population in India according to the census of 1931* (2.30).

Dr. A. Geddes.—*Bengal : aspects of its human geography* (3.0).

Upon the rice plain of Bengal the phenomena of race and culture still show affinities with those preserved in the tracts of hill country around it. These phenomena have, further, been influenced by (*a*) the local conditions of environment, affecting the mode of life there ; (*b*) natural routes both by river and by land, especially over the flood-free Old Alluvium ; (*c*) positions and sites favouring the rise of major settlements. While local conditions have influenced the distribution of tribes and lower castes, routes show marked relationship to the distribution of higher castes and of religious sects. Re-reading of physical and historic data seems to show that the western arm of the Ganges (Bhagirathi-Hughli) was important less because of the volume of its waters (as generally believed) than because of its position, the Padma (or E. Ganges) having long flowed E.S.E. and not being a ' new ' river, as is sometimes assumed. The movement of rivers is important to-day as in the past. It is now generally recognised that an abundant flow of river water is necessary to good crop production and peasant prosperity (with fish as protein food), and also to freedom from severe malaria and its associated high mortality.

Discussion on previous communications (3.30).

Tuesday, September 11.

Prof. W. N. Benson.—*Land forms in S.E. New Zealand* (10.0).

A series of younger sediments rest on the planed surface of ancient sediments and schists. A newer peneplain cuts with gentle obliquity across the younger sediments. Over part of its surface it has been covered by a thick and varied series of lava-sheets. Crust-folding occurring before, and during, the eruptions culminated after the volcanic activity ceased and was accompanied by faulting, the movements being continued into recent times. The present drainage system, partly antecedent to the folding, and partly consequent on the dislocated surface, has been modified by drowning. There

are minor effects attributable to recent uplift. The accordance between structure and topography is illustrated by several dissected block-diagrams.

Prof. G. B. Barbour.—*Physiography of Jehol, N. China* (10.45).

Prof. C. B. Fawcett.—*The relations between the advance of science (in geography) and the life of the community* (11.30).

(1) The end of the nineteenth century saw the practical completion of major exploration of the earth, and geographers were able to turn their attention to the systematisation of their knowledge, and the search for general principles. So the twentieth century has been marked by the rise of regional geography. Herbertson's essay on *The Major Natural Regions*, published in 1908, is a chief landmark.

Geographical work has been aided by several practical improvements, among which the International 1 : 1,000,000 map is prominent. It was begun about 1911 and is still far from complete, but it is an important result of systematic co-operative work, and it has stimulated both research in, and applications of, geography.

(2) The advance in detailed knowledge has helped to bring into use, or extend the use of, many materials which were not before known, or were known only in small quantities. The increased evidence of the interdependence of all the phenomena with which geography deals has done much to aid the trend towards a systematic planning for the human utilisation of the earth's resources, and to develop a mental attitude favourable towards synthesis and co-operation as a necessary advance from the extreme specialisation and competition of the nineteenth century.

(3) Fuller knowledge, and action based on it, could in many cases have prevented waste of human and material resources. Familiar examples are : (*a*) the lack of maps for the South African War, and for other purposes ; (*b*) the inadequate knowledge of tidal and other movements in the sea waters which reduced the efficiency of fisheries and of navigation ; (*c*) the lack of accurate knowledge of our freshwater resources which might have been of great value in this year's drought. In such cases the defect has been rather a failure to apply, and where necessary to extend, existing knowledge than entire absence of knowledge.

(4) The developments of means of communication such as the automobile and the airplane, particularly the former and the roads due to it, have modified nearly all aspects of land transport, and so the localisation of industries and the distribution of population. These are also vitally affected by the fact that within the present century public authorities have become responsible, to a large extent, for housing.

Prof. G. B. Barbour.—*Colour film of Crater Lake* (12.30).

Afternoon.

Excursion to Feughside.

Wednesday, September 12.

Mr. A. C. O'Dell.—*Population changes in Aberdeenshire from the Union to the present time* (9.30).

The purpose of this communication is to trace how far population changes are a reflex of the physical environment. The *List of Pollable Persons*

within the County of Aberdeen, 1696, is the earliest record and gives unusually full information. From the data in this record maps have been prepared showing trades and the density and distribution of population a decade before the Union. The MSS. records in the National Library of Scotland for 1750 and 1755 and the 1793–99 list in the *Statistical Account* have been utilised, while for the period 1801–1931 the official decennial returns have been used. Data given in the *Statistical Accounts*, various MSS. and printed reports and parish histories have been used to augment the eighteenth-century material.

The investigation shows that the highland parishes now have a scantier population than in the seventeenth and eighteenth centuries. This decrease is due as much to the higher scale of living as to the action of landlords. The areas of better agriculture show a peak in the middle of last century, followed by a decline, which, however, fails to bring the total below the 1696 level. Urban centres such as Fraserburgh and Peterhead show a stupendous growth in the last two centuries, followed by an almost negligible decrease. This may indicate that the saturation point of population has been reached with the present known means of subsistence fully developed.

Mr. F. H. W. Green.—*The distribution of settlements in the Moray Firth lowlands* (9.50).

The lowland coast of the Moray Firth is an area which is markedly distinct from the rest of Scotland in respect of its climate, and this, together with its remarkably well-defined topographic limits, suggests it as an obvious natural region. An attempt was therefore made to compare it in some detail with the other lowlands of the east coast, and, more especially, an analysis was made of its internal unity.

A study of the distribution of settlements is perhaps the readiest way of approaching the problem. The settlements are of three main types :

(1) Fishing settlements, of which several sorts may be distinguished. All the fishing activities, however, with the exception of the salmon fisheries, give rise to settlements which have remarkably little connection with the interior. 'Dual towns,' such as Nairn or Cullen, emphasise the truth of this point especially well.

(2) Market towns. Although such a town as Inverness occupies what is for more than one purpose an obvious site, some of the other regional centres do not show in their siting so clear a relationship to the factors of their physical environment.

(3) Isolated agricultural settlements, which, though of several types, show a marked absence of nucleated villages. The farming in the region, though varied, is predominantly arable, and reasons are advanced to explain the very even distribution of settlement within the limits of cultivation. A study of the latter, especially of the upper limit, forms a subject of considerable interest in itself, and an attempt has been made to understand the factors underlying the variations within the area.

Mr. K. H. Huggins.—*Geographical distribution of the early iron-smelting industry of Scotland* (10.10).

Of 40 ironworks in the midland valley, 10 were built prior to 1802 to smelt clayband ore with coke, the remaining 30 between 1825 and 1865 to smelt blackband ore with raw coal. Only 17 survived until 1921.

Relatively stable periods were :

(1) 1795–1825 ; 1806, 24 furnaces ; 17 in blast ; output 22,800 tons.
(2) 1860–1880 ; 1865, 181 furnaces ; 141 in blast ; output 1,160,000 tons.
(3) 1903–1913 ; 1913, 103 furnaces ; 87 in blast ; output 1,370,000 tons.

Great contrast between the scattered distribution in 1806, when cheaply mined coal, usually near the outcrop, was the dominant factor and sufficient clayband ore was easily obtained, and the marked concentration in 1865, when the location of the furnaces was dominated by blackband ores which occurred very locally in the Coal Measures and in the Limestone Coal Group. Coatbridge, with outcrops of blackband and splint, had the chief concentration, 61 furnaces. Furnaces were also built on all the newer discoveries : on the margin of the Ayrshire coalfield, near the Forth, and west of Glasgow. After 1880 home ore was subordinate to imported hæmatite. Fuel supply and relation to steelworks became important. Works closed in the east of Scotland, but continued in Ayrshire. Newly developed deeper parts of the Lanarkshire coalfield attracted steelworks and supplied splint to Coatbridge to smelt iron for them.

Mr. A. E. Smailes.—*The Lead Dales of the Northern Pennines* (10.30).

Lead-mining activity has given distinctive features to the dales of the northern Pennines, between the Stainmore Saddle and the Tyne Corridor, in addition to the obvious imprint it has left upon the landscape.

The miners have usually been small-scale farmers also, with the result that the pastoral dales farming is of a rather intensive type, with cattle-keeping on small-holdings a strongly marked feature.

The generally high situation of the mines (due to geological factors), together with the dual occupation of the miner-farmer, have contributed to extend the zone of cultivation and settlement to remarkably high altitudes in these dales, and lead-mining has not obscured the dispersed pattern of the pastoral settlement.

The decline in lead-mining since the 'seventies has been offset only to a small degree by development of production of associated minerals, and of quarrying. There has been a resultant large and general decrease in population, but these dales show a population ' residue ' from the lead-mining days.

Although forming a distinctive group, the Lead Dales are not characterised by unity of life. This lack of unity is related to the divergent drainage. The dale-communities are segregated from each other, and life is orientated outwards. The seclusion of the dales is being broken down by the development of communications, which is linking each of them more closely with the more important regions outside.

Miss Florence C. Miller.—*Population changes in Wessex in the twentieth century* (10.50).

Geologically the area is divided broadly into Chalk and Tertiaries. The chalk shows decreases of population with exceptional areas of increase. The tertiaries show increases with exceptional areas of decrease. Actually the total population affected by decreases is less than that affected by increases.

An important relation is that between population changes and migration. The excess of births over deaths is general. Migration takes place from the chalk. It takes place to the tertiaries. It takes place from the Isle of Wight. Population migrates from the chalk on account of changes in

farming methods. It migrates from the tertiaries on account of losses in intensive cultivation.

Increases in population are usually connected with good communications, residential development, permanent military establishments, outgrowth from large towns.

Discussion on previous communications (11.10).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Thursday, September 6.

Dr. H. HAMILTON.—*The changing organisation of the Scottish fishing industry, 1880–1914* (10.0).

The economic organisation of the Scottish fishing industry was fundamentally changed in the thirty years before the Great War. Hitherto fishing had been widely dispersed all round the coasts of Scotland, and white fishing and herring fishing, the two main branches of the industry to-day, were undifferentiated, the same boats and the same fishermen taking part in both. With the introduction of the steam trawler in 1882 white fishing quickly became a highly organised and capitalistic industry, with Aberdeen as the greatest fishing port of Scotland. The change in the organisation of the herring industry came slightly later and was of a different order. The greater mobility of the steam drifter resulted in the amalgamation of the various herring fishings into one continuous one extending over nine months of the year, while the landing and curing of the catch came to be concentrated at a relatively small number of ports which had suitable harbour accommodation. Further, the joint-stock method was not favoured, and the fishermen continued to own the vessels and the nets as they had done in the days of the sailing craft, but the greater cost of the steam vessels made it necessary for them to borrow from the banks, from curers, fish salesmen and other merchants, who thus came to exercise considerable control over the industry.

Mr. W. H. MARWICK.—*The economic development of Victorian Scotland* (11.0).

Between 1837 and 1901 Scotland passed from a virtually self-contained national economy to an almost regional subordination to that of Great Britain. As its basis, the textiles gave place to the heavy constructional industries, dependent mainly on export. Trading relations were maintained with the Baltic and North America, and extended to the Orient, Africa and South America.

Scottish economic expansion had been late and rapid ; hence features of a paternalist society, fostered by geographical conditions and religious teaching, survived from the agricultural regime, notably in the conduct of mining and in social provision at many works and factories. These were gradually superseded by state intervention.

Individual enterprise was further modified by the prevalence of partnerships, often ephemeral and sometimes involving complicated interrelationships. With the enactment of limited liability, joint-stock companies

became common, both in the transformation of old businesses and the establishment of new ones. The world-wide tendency to combination was especially illustrated in banking and railways, both highly competitive at the outset. The financing of industry was facilitated by the foundation of stock exchanges and the introduction of investment trusts. Labour organisation was weak, while charitable associations had some influence in modifying social conditions.

Mr. E. D. McCallum.—*Recent economic changes in Scotland* (12.0).

The object of this paper is to describe some of the more important economic changes which have taken place in Scotland in the post-war period. In the first place, changes in the size of population and in the age, sex, regional and industrial distribution of the population are considered. Secondly, an account is given of changes in the volume of employment and unemployment in Scottish industries and services since the war. Thirdly, changes in the industrial structure of Scotland are examined. Information on this topic is derived mainly from statistical tables provided by the Ministry of Labour, showing the industrial distribution of persons insured under the Unemployment Insurance Acts in Scotland for the years 1923–32 and the number of these persons recorded as unemployed. Finally, a brief account is given of changes in the industrial and agricultural output of Scotland and in the volume of Scottish export trade.

Friday, September 7.

Presidential Address by Mr. H. M. Hallsworth, C.B.E., on *The future of rail transport* (10.0). (See p. 119.)

Prof. W. F. Bruck.—*Risk and its significance in modern economy* (11.30).

A. Three types of economic organisation : I. Ideal type of liberal economics (with markets. Unit based on individual enterprise). II. Ideal type of ' domination ' of economic sphere ; purely socialist planned economy (without markets. Unit based on Department of Public Administration). III. Transition between I and II (limited market economics with limited private enterprise and ' invasions ' by control of the State, public bodies and big business).

Practical application.—Type II does not exist, even in Russia. Type I dominant in Britain, 1850–1914. Type III is present type of world economy.

History of development.—(*a*) First industrial revolution ; (*b*) second industrial revolution (industrialisation of agrarian and overseas countries and other changes).

Risk and spreading of risk in these historical periods.—Union of functions in the capitalist *entrepreneur*. Then division of labour transferred risk and other functions of *entrepreneur* formerly his prerogatives to other institutions and persons. Progressive impersonalisation of undertakings (cartelisation, trustification, invasion of public control).

German history as example.—Since 1700 pronounced progressive state-socialism, interrupted only by very short semi-liberal period. After war most important trades (industries, transport, banking) largely controlled by state or big business. In contrast to liberal nations, greater part of economic functions transferred to Public Administration. Publicly controlled capital makes State chief bearer of capital risk. At the same time, State-socialist State grows in Germany into a ' Sozialstaat ' (state as moral trustee of its

citizens in contrast to authoritarian State, 'Obrigkeitsstaat'). Social risk, a new development of State-socialist Sozialstaat, runs parallel to capital risk, both growing especially in second industrial revolution with non-adjusted supply and demand in time of enormously increased productive capacity by rationalisation. Historical sketch shows progressive sensitiveness towards trade cycle.

B. *How to manage a semi-planned economy of type III.*—Methods of corporate systems based on partial exclusion of market economy; complete exclusion impossible in States of Western culture. Therefore must have a construction serving the transitional stage, i.e. both planned as well as liberal economy. Application of German mixed public and private enterprise side by side with private enterprise and purely public administration with departmental units. Description of this mixed enterprise (history, successes, economic and legal construction, functions and rational adaptation to them). The three types of special risk-transference, two personal, the modern cost accountant and the applier of trade cycle forecasts, and one impersonal, the risk spreading compensation-machinery of German cartel type.

Monday, September 10.

Miss E. F. Stevenson.—*Economic anomalies of unemployment relief* (10.0).

While work is the only satisfactory form of unemployment relief, the provision of work is difficult, particularly in periods of depression. Similar difficulties arise in all forms of Public Assistance; and it is therefore advisable to consider what are the general economic principles of public assistance, how far they are applicable in the case of unemployment, and whether changes in organisation may be expected to remove the existing anomalies.

The whole question may be regarded as a problem of the use of economic resources and of the distribution of the national dividend, and is obscured by viewing it as a problem of administration of relief.

Discussion on *Economic planning* (10.45).

Prof. D. H. Macgregor, M.C.

Prof. A. Gray.

Prof. W. F. Bruck.

Sir Josiah Stamp, G.B.E.

Tuesday, September 11.

Mr. J. K. Eastham.—*The tin control scheme: a study in regulated marketing* (10.0).

The purpose of this paper is to discuss some of the major problems of restriction of supplies of raw materials in the light of recent developments in the tin industry. The capital structure and technical conditions of the tin industry are briefly reviewed, and an attempt is made to estimate the relative importance of technical costs and the capitalisation of the concern in determining the attitude of the individual producer to restriction.

The following problems are then discussed :

(*a*) The efficacy of restriction of supply as a remedy for cyclical depression.
(*b*) Speculation and the amplitude of price fluctuations.
(*c*) Centralised stock holding as a technique of price manipulation.

Prof. F. W. Ogilvie.—*The significance of international trade accounts* (11.0).

Mr. S. Rowson.—*The value of remittances abroad for cinematograph films* (12.0).

Wednesday, September 12.

Mr. R. B. Bryce.—*The wheat situation and state control* (10.0).

The paper deals first with the present statistical wheat position and the trends and events leading up to it. This brings out the economic problem involved in the low returns to the growers, relative to their former returns and to those of other producers. This in turn has brought about, in places, severe social problems with political repercussions.

The analysis is then made of some factors in the supply of and demand for wheat which lie behind the great relative fall in its price. The structure of both production and marketing is related to this as well—with special reference to possibilities of governmental control. The influence of the general economic depression is also treated.

On the basis of this analysis an examination is made of several of the many Government attempts to improve the position of the wheat growers. Comparisons are made between the schemes of various countries, and these are related to national agricultural policies. Finally the attempts at international control or agreement are considered and the possibilities of their success discussed.

DEPARTMENT OF INDUSTRIAL CO-OPERATION (F*).

Thursday, September 6.

Afternoon.

Discussion on *The need for a technique of economic change* (3.0).

Sir Josiah Stamp, G.B.E.

Under conditions of increasing population existing aggregate supply may go on without quick contraction, even though individual demand is partly redirected into new channels (e.g. less bread per person, but more persons wanting it). Supplies of new products may be provided by additional workers without calling on existing producers to change their occupations, and avoiding the overcrowding of those occupations by new workers and, therefore, no dynamic force has so far existed for transference for unemployment caused by technical change, and the need for a technique has not been seriously considered. But as populations get stationary, and as technical change becomes more rapid, vested interest in workers' special skill becomes more in danger. Apart from increasing real income, every

new demand in spending an existing income means a less demand for old products, and problems of unemployment through displacement become more frequent. Two cases are distinguished : (*a*) innovation which enables old products to be supplied more easily, and thus frees purchasing power and workers simultaneously for new objects, and (*b*) innovation causing rival satisfactions in use (radios *versus* pianos) or later sources of supply slightly cheaper. The latter case is the more acute. Under a planned society, the consumer can never get his own way and whim to the old extent, and the transfer could be made gradually, protecting old producers (i.e. skill and capital) from immediate extinction. Under an individualistic society, several palliatives are possible for examination :

(1) State-aided transfer of labour.
(2) Graduated protection from foreign competition.
(3) Common aid to obsolescent industry or districts.
(4) Compulsory special funds and additions to competitive costs, towards obsolescence, from new industries.
(5) A ' contracting ' industries' tribunal.

It is often only possible in retrospect to distinguish between depression and displacement. Sudden death and healthy bankruptcies are alone consistent with a highly individualistic society, but the new conditions make some modification essential. Displacement of labour has a human and social appeal, but over-rapid destruction of capital is also a social evil, if it undermines one of the essential conditions, security, in which alone capital would voluntarily come into existence.

Mr. N. F. Hall.

The demand for a technique of economic change arises from an instinctive feeling that the economic system does not sufficiently rapidly avail itself of the new knowledge placed at its disposal by scientific research, and that consequently society in its rôle of consumer is deprived of benefits to which its growing knowledge and command of natural resources entitles it.

The need for a technique of economic change is generally admitted, the difficulty is to discover the nature of the economic problem to which rapid developments in scientific knowledge give rise. The first part of the paper, therefore, reviews the general principles of economic theory with the object of isolating the obstacle to change. This obstacle is found in the increasing degree of specialisation both of men and capital equipment which technological change requires. This specialisation acts cumulatively as an obstacle to further change. It does so by increasing the zone of ' uncertainty ' as a constituent element in the economic system.

The second part of the paper discusses the technique necessary to overcome this ' uncertainty ' ; its bearing upon changes in prices and output of capital goods, and through these upon the general level of economic activity and employment. The paper concludes with a discussion of the bearing of changes in the zone of uncertainty upon monetary and investment policy.

Mr. Kenneth Lindsay, M.P.

Large-scale production, specialisation, speed of mechanisation are producing new social phenomena. The distressed area dependent on an old economy ; the derelict villages dependent on a single industry ; the new estate.

Areas of administration for utility and social services ; transport, electricity, water, gas, town planning ; housing, hospitals, education, relief.

The strain on local government, need for new areas. Age-groups must be studied by industries and localities.

Where to live and where to work. How far can planning of social services anticipate economic changes ? A national survey wanted.

Friday, September 7.

Afternoon.

Discussion on *Education for business management in Scotland* (3.0).

Dr. H. Hamilton.—*Education for commerce in Aberdeen University.*

A Department of Commerce was instituted in Aberdeen University in 1919, its purpose being to meet the needs of those preparing for careers in commerce and administration by providing opportunities for the study of subjects cognate to their future pursuits. The essential basis of such a course consists of economic subjects—political economy, organisation of industry and commerce, banking, currency and foreign exchange, and these—together with accounting and business methods, mercantile law, geography, statistics, industrial psychology and a modern foreign language—are compulsory for all candidates. The curriculum includes at least two other subjects chosen from a wide selection, thus giving the student the opportunity to specialise in foreign languages, in scientific subjects, or in advanced economics.

Down to 1933, 117 students had graduated, and the occupations represented offer an interesting study. In that year the representation was as follows : business, 43 ; chartered accountants and accountants, 21 ; teachers, 19 ; banks, insurance and telephone companies, 7 ; law, 3 ; Inland Revenue, 2 ; secretarial work, 2 ; railways, 2. Of the total number of graduates about 35 were abroad, mainly in Africa, India and the Far East ; about 28 in England, chiefly in London ; and about 50 in Scotland, a number of whom were training for accountancy, for law, teaching or medicine.

Mr. Garnet Wilson.—*The Dundee School of Economics and Commerce.*

Monday, September 10.

Afternoon.

Discussion on *Visual methods for the presentation of statistical and other data for the use of business executives* (3.0).

Mr. A. G. H. Dent.—*Graphic methods for business executives.*

Graphic and other visual methods of analysing and of presenting business data have developed in industry because they have definite advantages compared with pure figures. These advantages may be summed up as easiness to prepare, wide scope, great condensing power, and comprehensiveness ; the capacity to show long period trends, relationships between various series, and characteristic variations, such as seasonal and cyclic fluctuations. Combined with statistical methods, graphic technique enables numerous problems in management to be shown clearly and vividly, and provides a valuable analysis of conditions.

The chief divisions of visual methods are :

(1) Charts, graphs and diagrams ;
(2) Models, mechanical devices and maps ;
(3) Special systems ;
(4) Symbols.

The most commonly used line charts are the plain arithmetic chart, its companion, the ratio chart, the Z chart, incorporating the moving annual total, and the Gantt chart. The more vivid types such as bar, circle, mirror bar, square, etc., are now well known. Maps are used for such work as the sales control of a large territory, subdivided into branch office areas. Models are generally produced for some special problem, to illustrate the operation of several conditions. Special systems, usually consisting of signal devices, including coloured discs, tabs, etc., have been marketed by several firms for such uses as sales management, operative and credit control. Symbols are of more general application and appear commonly in propaganda matters, and to simplify numerical facts, as in the Neurath technique.

All these methods have their particular fields of application, and have passed through the stage of being regarded as an interesting novelty into the condition of useful aids to business executives.

The application of such methods must always be justified by their superior utility to previous methods, and for this reason they require close study before use in any given circumstances.

Mr. Mark Barr.

Tuesday, September 11.

Joint Discussion with Section L (Educational Science, *q.v.*) on *The planning of a national policy of technical education and industrial recruitment* (*Section L room*) (10.0).

Wednesday, September 12.

Discussion on *The use of the experimental method in the field of ' Industrial Relations '* (11.0).

M. H. Dubreuil.—*Autonomous groups in industry.*

If the industrial concern has not yet reached that state of harmonious unity that nature has realised among living beings, the reason is because we obstinately seek to push life into it by means of uniform regulations which take into account neither the peculiarities of its technological groups nor of the existing differences between the individuals of whom the groups are composed. Like a living being, the business is nevertheless constituted of a *congeries* of differentiated organs responsible for distinct functions such as are performed by the human organs that assure the continuity of our existence. That is why human industry, which has already had recourse to so many different branches of science, must pursue this progress further by applying the laws of a new science for the organisation of its internal life. Drawing inspiration from the life of organic beings as revealed by the science of biology, industrial organisation will learn the value not only of the division of functions but also of their autonomy. ' Industrial Relations ' at bottom are not, or at least ought not to be, different in nature from organic relations.

The question, then, is not really one of resolving its conflicts so much as to prevent their occurrence by means of a convenient circulation of the forces which should be capable of combination instead of opposition. If, then, we cease to regard the business as a *bloc* for which there could only be an *en bloc* solution, we can, by directing our attention successively upon its subdivisions only, proceed with smaller risk along lines of experimental research. For example, profit-sharing applied to the total personnel of a business is a form of *en bloc* attempt at the solution of the problem of remuneration of labour. If we reduce this problem to the dimensions of a technological group, we also reduce the extent of the difficulty: it becomes a question of resolving the problem of digestion by means of the stomach, and that of respiration, by the lungs. Then we shall begin to build a business in the image of those organic beings that nature has evolved. The imitation of natural organisms should lead to the subdivision of businesses into autonomous groups.

Prof. F. Meyenberg.—*Improvements in industrial relations arising from the intervention of the management consultant.*

The process of 'division of labour' that is economically necessary in every industrial concern is liable to give rise to various forms of internal friction which, whether traceable mainly to material facts or to personalities, must be removed, or at least diminished, by those responsible for organisation.

For this task the independent management consultant is often better placed than an employee of the concern in that:

(1) Being free from preoccupation with day-to-day detail he can give his whole time to questions of organisation.

(2) Being free from departmental bias he can envisage the harmonious organisation of the concern as a whole.

(3) Through his experience in investigating different branches of industry he recognises the underlying principles common to all, and thus is less prone to overrate non-essential details.

(4) He is free from that workshop blindness which so often results from a man's having worked many years in the same factory.

If the best possible results are to be obtained the following requirements must be fulfilled:

(1) *On the part of the management consultant.*—He must have long acquaintance with the theory and, more important still, of the practice of the main managerial functions such as purchasing and selling, storage and transport, production, methods of payment of personnel, cost-accounting, book-keeping, inspection and finance. He must possess a high degree of discretion, tact and knowledge of human nature if he is to gain influence by consultation rather than by command. Apart from his work as a consultant he must be entirely independent and disinterested, both materially and morally.

(2) *On the part of the directors of the concern.*—They must give the consultant free access to all the facts of the business and require their employees to do likewise. Criticism, even when adverse, of measures taken by the managing director must be regarded as in the interests of the concern as a whole so long as it is offered in an objective and inoffensive manner. The managing director, however, must never forget that he alone is responsible for the success of the business, and should therefore follow the consultant's advice only if he is personally convinced that it points in the right direction.

A general description was given of the development of such consulting work, with illustrations of the practical application of the foregoing ideas.

Mr. R. J. Mackay.—*Some experiments in readjustment of relations between finance-capital, management and operative labour.*

It has been found possible, without recourse to special legislation or state-wide revolutionary change, to make small-scale yet significant experiments in readjustment of relationship as between ownership, management and operation in business concerns. Limitations of profit-sharing and co-partnership as conventionally understood. Possibilities and limitations *qua* opportunities of reward of a reversal of the customary relationships between working personnel of all grades on the one hand, and absentee ownership on the other. A case for the subdivision of sizeable businesses into relatively independent responsible groups of working personnel, and its bearing upon suggested wider utilisation of biological laboratory technique for vocational selection, guidance and placement of existing and potential industrial personnel of all qualities. A plea for further experimentation.

SECTION G.—ENGINEERING.

Thursday, September 6.

(Note.—For joint session, Sections A, G, this day, on *Technical Physics*, see entries following Section A, pp. 283 *seq.*)

Presidential Address by Prof. F. G. Baily on *Sources of cheap electric power* (10.0). (See p. 145.)

Mr. W. T. Halcrow.—*Scottish hydro-electric stations* (11.15).

The first part of the paper deals briefly with the water power resources of the British Isles as a whole. Mention is made of the work carried out by the Water Power Resources Committee and the effects upon development of that Committee's report.

The author refers to the many difficulties with which the promoters have to contend in obtaining sanction by Act of Parliament for the construction of large schemes, the promotion costs of which amount to large sums of money, and then goes on to describe and give examples of the three main types of developments in Scotland; namely, (1) those working on a fully regulated flow at a constant load; (2) those on a fully regulated flow but working on a varying load and used for general purposes; and (3) those with a partially regulated flow, having little or no storage and worked in conjunction with steam stations.

In the last part of the paper the author discusses the relative advantages of steam and water power stations and points out that the cost per unit generated at a large water power station is, contrary to general belief, considerably less than that of a steam station of similar capacity and load factor.

The paper is accompanied by a map of Scotland indicating the positions of the various schemes.

Mr. F. S. Anderson.—*Granite and granite quarrying* (12.15).

Nowhere in the whole of Great Britain is there such a large granite area as in North-east Scotland, and Aberdeen has been regarded as the chief centre of the granite trade in this country for over two centuries. Systematic quarrying was first started in this area about 1720, but until the end of the eighteenth century the methods of quarrying and hewing the rock were very crude indeed. In Aberdeenshire quarries the quality of the rock improves with the depth, and the best rock is found in masses separated from each other by bars of inferior material. The paper gives a brief history of the development of the granite industry, and an outline of the method of quarrying, manipulating, crushing and screening granite at Rubislaw Quarry, which, opened 159 years ago, is now 370 ft. deep.

Granite is the most durable rock substance quarried and worked by man. Its uses and purposes are numerous and varied, and the author discusses those purposes for which the durability, strength and beauty of granite make it pre-eminently suitable.

Afternoon.

Visit to Rubislaw Quarry.

Friday, September 7.

Mr. R. W. Allen, C.B.E.—*The application of Diesel engines to trawlers and their operating gear* (10.0).

The British fishing industry has encountered difficult times in recent years. The fishing grounds round Great Britain have been overfished, and there has been greatly increased competition from subsidised foreign fishing fleets. Tariffs and other manifestations of the trend towards national self-sufficiency have added to the difficulties of the industry.

It has been evident for some time that greater radius of action, and increased speed to and from the fishing grounds, at least so far as the larger vessels are concerned, are essential if there is to be a renewal of prosperity in the industry. The Diesel trawler meets these and other requirements of propulsion and winch operation very satisfactorily.

In this paper the lines along which Diesel trawler development has already taken place, and is likely to continue in the near future, are discussed and summarised. The various types and sizes of trawlers are dealt with broadly under four headings, the characteristics and requirements peculiar to each class being examined from the point of view of Diesel propulsion. The probability that speed-reduction gear will be adopted in future, permitting a high engine speed with a relatively slow propeller speed, is discussed ; whilst reference is also made to the possibilities of Diesel-electric development for large trawlers.

Prof. C. H. Lander, C.B.E., and Dr. E. W. Smith, C.B.E.—*The collection and distribution of gas in bulk* (11.0).

Distributory systems developed in other countries. Distributory systems within the gas industry in more highly populated areas in Great Britain, including London, Birmingham, South Yorkshire and Manchester. Facts influencing cost of distribution. Engineering problems. High- *versus* low-pressure. Zoning of gas distributory systems in highly populated areas. Influence of location on demand *vis-à-vis* sources of coal, with

special reference to waterways and railway systems. Comparison between distribution problems of gas and electrical industries. Effect of tariffs on distribution policy. Bearing of zoning on utilisation of coke-oven gas. Factors governing cost of gas. Capital charges per therm. Availability of coal supplies. Effects of costs and qualities of coals.

It is suggested that the subject merits a closer and more comprehensive examination, having for its object the ultimate zoning of the gas industry into several areas, each of which will be co-ordinated as regards the gas distributory systems.

In the view of the authors such co-ordination does not necessarily entail financial absorption. It appears that the lessons of the development of the electrical industry are not applicable to the co-ordinated distribution problems of the gas industry, but that nevertheless an equally comprehensive treatment of the gas industry should be undertaken.

Mr. James Abel and Mr. J. Duguid.—*Paper-making* (11.30).

Since the last visit of the Association to Aberdeen forty-nine years ago, advancement in the papermaking industry has been very marked. There are five paper mills on the outskirts of the city, and as in other industries it has been found beneficial to bring the steam boiler and power plant up to date. The perfection of the 'pass-out' steam turbine, which enables the papermaker to withdraw the necessary process steam required, has definitely displaced the old steam engine, and the use of steam boilers working at different steam pressures is now no longer necessary.

In the beater room, the Hollander continues to be the most popular type of beater, although there have been many attempts to produce a substitute. The electrical sectional drive on the papermaking machine has been largely responsible for the success of the modern high speed machine running at 800 to 1,000 ft. per minute. The advancement in design on the making machine has been largely brought about by the production of rigid frames and rolls of greater length, the introduction of the suction couch roll and multiple press rolls. For fine mills the adoption of the centrifugal system of separating heavy and light particles of foreign matter from the pulp is worthy of note, and improvements have been made in strainers, backwater systems, suction boxes, etc. Amongst recent innovations, the application of the vacuum principle of drying the paper deserves attention.

Even with the present perfection of the making machine, there are many problems remaining for the imaginative engineer.

Afternoon.

Visit to Telford Exhibition, Gordon's College: opening of exhibition by Sir Alexander Gibb, G.B.E., C.B.

Monday, September 10.

(Note.—For joint session, Sections A, G, this day, on *Technical Physics*, see entries following Section A, pp. 286 *seq.*)

The Reduction of Noise:—

Sir Henry Fowler, K.B.E.—*Summary of Report of Committee on Reduction of Noise* (10.0).

The Chairman wrote to the *Times* inviting reasoned opinions from members of the public as to the noises which caused them most discomfort

and inconvenience. A very large number of replies were received and analysed. They led definitely to the conclusion that the worst offenders were inadequately silenced motor bicycles and sports cars, then motor horns, then other road transport noises, and then aircraft.

The Committee decided to concentrate upon the reduction of exhaust noise of motor bicycles, but they have also arranged that a paper on the effectiveness and offensiveness of motor horns shall be read by a representative of Messrs. Lucas.

In order to assist in the establishment of an authority to which types of motor vehicle could be submitted for test of approved silence, Dr. Davis, of the National Physical Laboratory, has investigated which instrument is most suitable for determining whether the exhaust noise of a vehicle exceeds a specified maximum, and Wing-Commander Cave-Browne-Cave, at University College, Southampton, has carried out experimental work in conjunction with the Motor Cycle Manufacturers to determine how much reduction of exhaust noise can reasonably be effected without loss of power.

A grant of £10 was made for correspondence, but the work at Southampton was rendered possible only by a donation of £50 from Lord Wakefield to University College for that purpose. A supplementary grant of £24 by the British Association was made in May, 1934.

The Committee considered that very satisfactory progress has been made, but defer their recommendation for further action until they have heard the discussion upon the three papers which have been arranged.

A demonstration was given in the afternoon by motor bicycles as sold and as fitted with silencers based on the work at Southampton. There was also a demonstration of various types of motor horn.

Wing-Commander T. R. Cave-Brown-Cave, C.B.E.—*The reduction of motor bicycle exhaust noise* (10.10).

The nature of exhaust noise is reviewed and the principles of certain types of silencer are examined.

Preliminary tests were made to determine the most satisfactory type for the suppression of noise with the minimum loss of power.

These having proved encouraging, arrangements were made with the Motor Cycle Manufacturers to lend to University College, Southampton, one representative machine of the 4-stroke type and one of the 2-stroke type.

These machines were installed so that the power could be accurately measured and the influence of alternative types of silencer determined.

As a result of this work, a silencer has been evolved for each type which produces a great reduction of exhaust noise and gives a small increase rather than a decrease of power as compared with the exhaust silencers as sold.

Performance curves of the engines with various types of silencers are given, together with details of the silencers and the principles on which they are based.

Dr. A. H. Davis.—*The measurement of noise* (11.0).

The paper reviews the bases and practice of noise measurement by means of aural and objective instruments.

In aural measurements different observers agree within limits, but it appears to be necessary to average the results of several observers in order to get a typical result with precision.

Objective instruments giving a meter reading corresponding to the average aural judgment are obviously desirable. Their theoretical foundation

is not wholly rigorous. Nevertheless there are ways of overcoming the more serious of the difficulties, and objective meters have been used successfully for measuring moderate and loud sounds of very varied character. The meters are often more reliable than individual observers in assessing the average judgment. The difficulties are minimised and the apparatus is simplified if the sounds concerned are of similar character and of the same order of loudness. A test within these limits will determine whether noise of a given kind or from a given type of machine exceeds the loudness specified as the maximum permissible, and appears to be within the scope of objective noise meters, subject possibly—in present conditions—to preliminary test and adjustment of the meter for the type of noise concerned.

Mr. E. O. Turner.—*Motor horns—effective and offensive* (11.50).

It is endeavoured to examine by what means motor horns may be rendered less offensive to road users without reducing their effectiveness.

The chief types of horns which have been in wide use are reviewed. Non-electric types are first mentioned. Electric horns and oscillograms of their sounds are then considered. They are shown to be most effective when resonance is obtained between the fundamental or a harmonic of the sound source (generally a vibrating diaphragm) and an additional vibrator, resonance chamber, or air column.

A tentative conclusion is drawn that the least offensive signal should be strictly periodic and complex in wave shape, avoiding both pure tone on the one hand and an undue number and amplitude of non-harmonic overtones on the other.

The advantage gained by care in the choice of position and method of mounting on the car is referred to, and other means of reducing offensiveness are considered : the use of staccato signals and the elimination of horns having comparatively long starting and stopping periods, and optional soft and loud signals for town and country use.

Reference is made to regulations and by-laws regarding warning signals in force in other countries, and to other traffic regulations likely to affect the use of horns.

Afternoon.

Excursion to Bridge of Dee for demonstration of noise reduction.

Tuesday, September 11.

Prof. Sir James B. Henderson.—*Development of invention as a stimulus to economic recovery* (10.0).

The history of industrial progress shows that it has been due in large measure to a combination of inventors with scientific vision, with promoters having capital and economic vision. Since the war this type of combination has been greatly reduced, and the only type of invention which has been in demand has been one which will further reduce employment by saving costs of production.

Industrial research, which has been greatly stimulated, is looking after the industry of ten or more years ahead, whereas quick recovery is to be found in the development of inventions lying dormant in our patent records. This important branch of our industry requires urgent stimulus. At

present it is much easier to find fifty thousand pounds for the commercial working of an invention which has been developed to the commercial stage than it is to find five thousand for its development.

Development of inventions is definitely outside the purview of the research associations and requires propaganda to educate a new generation of capitalists to act as promoters, and to bring them in touch with inventors. Some steps have already been taken in this direction, but many more are wanted. It may be thought that the development of inventions is one of the functions of industry, but the history of invention and the experience of many inventors proves the contrary, with perhaps the one exception of inventions which will reduce the costs of production. All of these tend to increase unemployment, at least temporarily.

Mr. H. Hallam and Prof. R. V. Southwell, F.R.S.—*Researches in impact testing* (11.0).

Investigations relating to the testing of materials by impact were described (informally) at the York meeting (1932). A new type of machine was employed, and a new method for applying the impulsive loading. The results were satisfactory both as regards consistency and as showing that the energy absorbed in fracture satisfies fairly simple dimensional laws.

The present paper describes a later model of the same machine, designed to test specimens of half the size used previously, and embodying several modifications which experience has shown to be desirable. The results of recent work relate to—

(1) the detection of ' notch-brittleness ' ;
(2) the ' age embrittlement ' of mild steel at room temperatures ;
(3) dimensional aspects of the test, as revealed by tests on two sizes of specimen, loaded both slowly and fast.

Some tentative conclusions from dimensional theory are advanced, and the paper ends with an account of recent experiments which show that notch-brittleness can be detected by static tests in bending, although in a tensile test the faulty material behaves like sound material, whether the specimen be of the ordinary type or notched. The practical implications of this last result are discussed.

Report of Inland Water Survey Committee (11.45).

Capt. W. N. McClean.—*The flow of the river Dee* (12.0).

The author describes how the gauging of the river Dee has been inaugurated with the object of giving a practical example at this meeting of how river survey may be carried out.

Central and local co-operation has resulted in the projected installation of four water level recorders at sites about 20 miles apart along the river and in facilities for flow gauging at Cairnton. The apparatus and the surveyors are on the site, and an actual illustration of the flow gauging will be given on the site at Cairnton during the afternoon of September 11.

Low flow measurements were made by the Corporation of Aberdeen last autumn, and some surface velocities were measured by floats during the April floods of this year. During the coming autumn and winter it is hoped to complete the flow gaugings for all stages of the river at Cairnton and, should opportunity be presented, at other sites where water level recorders have been established.

The amenities, use and control of the river, with special reference to

fishery and water supply, are referred to ; and it is indicated how the knowledge of rainfall, flows and water levels will be a guarantee against developments which would be harmful to the amenities and legitimate use of the river and its water.

The general scope of the water survey is outlined by a map of the catchment areas showing rainfall and physical characteristics.

The methods of keeping records are outlined and the results, arrived at from these records, are illustrated by the diagram of a long and intense flood on the Inverness-shire Garry—the diagram showing clearly the correlation of rainfall, run-off and storage during the passage of the flood, and the important correlation of run-off and storage during the following dry period. The flow gauging methods are briefly referred to, and the great value of systematic water level records at permanent and temporary stations is emphasised.

AFTERNOON.

Excursion to Banchory, Cairnton and Wood End House for river-gauging demonstration

Wednesday, September 12.

REPORT OF COMMITTEE ON STRESSES IN OVERSTRAINED MATERIALS (10.0).

Prof. B. P. HAIGH.—*The lower yield point in mild steel : measurement, specification and application in design* (10.10).

It is generally believed that considerable reductions in the weights of plates and rolled sections used in mild steel structures may be justified by accumulated advances in constructional technique, and particularly by the more general adoption of welding in lieu of riveting. As a means to this end, affording a more reliable basis for the estimation of the actual strength of structures, the more general use of the so-called ' lower ' yield point is recommended in lieu of the ultimate tensile strength.

A few tests are described, and references are made to others, to show how the ' lower ' yield point is readily measured in mild steel, after plastic strain has commenced under a load that may be considerably greater. It is shown that the lower yield point value is more consistently reliable than the higher value more commonly quoted.

A draft specification is submitted for consideration with a view to adoption by the standardising Institutions. It is suggested that this specification should be standardised for the use of those who may desire to use it, although it should not at present be substituted to replace the current specification of the higher yield point.

Tests on welded joints in beams, and on welded high-pressure penstocks for the development of water power, are described in detail to show how the results observed in practice may be precalculated in a reliable manner and in exceedingly simple ways by using the lower yield point as a basis of calculation in lieu of the less reliable bases provided by the ultimate tensile strength or the limit of proportionality of the materials used.

Mr. R. T. MEDD.—*Aerial cableways* (11.0).

Definition. Origin of cableways in Aberdeen granite quarries and historical development. General consideration of the carrying capacity

of wire ropes and of the sags of ropes and spans employed. Effect of stretch of ropes. Functions, range and limitations of cableways. Descriptions of the different types of cableway and their applications to and suitability for different uses and situations. Particulars of some special types and a more detailed description of two or three particular installations.

Dr. R. H. Evans and Mr. J. Thomlinson.—*Shear stress distribution in reinforced concrete beams* (11.10).

The paper describes measurements of strain with the object of determining the distribution of shear stress in both plain and reinforced concrete beams. The strains have been measured in three directions with extensometers having a gauge-length of one inch. Reference is also made to the horizontal and vertical stress conditions and to the position of the neutral axis.

The results show that concentrated loads have considerable influence upon the general stress conditions, the shear stress being a maximum not at the neutral axis, but at some point between the axis and the loading point. The characteristic shape of the graphs obtained can also be explained in terms of the radial stresses produced by concentrated loads. The observed shear stresses in sound concrete beams are often somewhat less than those estimated and increase very rapidly with the appearance of cracks in the concrete. In that portion of the beam situated above cracks the shear stresses are found to be considerably higher than those calculated. Observations are also made regarding the variation of the stresses induced in both the vertical and inclined reinforcing rods for shear.

Report of Committee on Earth Pressures.

Report of Committee on Electrical Terms and Definitions.

SECTION H.—ANTHROPOLOGY.[1]

Thursday, September 6.

Mrs. M. M. Hasluck.—*The flattening of Albanian heads and the evolution of European cradles* (10.0).

The conspicuous flatness of Albanian heads at the back has long puzzled anthropologists. Other Balkan races say it is artificial, produced by strapping babies to boards, but Albanians deny this, and foreign investigators have always found Albanian babies in cradles equipped with an ordinary pillow and mattress. In 1931, however, accident enabled me to solve at least part of the riddle. In certain well-defined areas Albanian babies are really strapped at birth on a rough board—not to flatten their heads, however, but only with the superstitious purpose of making their hold on life as firm as the board or the practical purpose of making their bodies easier to handle. As the majority are left only a single day on the board before being transferred to a proper cradle, there seems no time for the skull to be seriously affected. Besides, heads are flatter in South Albania where no boards are used than in North Albania where they are.

Various derivatives of the board exist up and down the country, and when these preliminary cradles are set beside the varieties of cradle proper, one

[1] In the absence of the President owing to indisposition, the chair of this Section was taken by the Rt. Hon. Lord Raglan, Vice-President.

sees how European cradles evolved in the course of ages from boards. Only two stages in this evolution appear to be missing in present Albanian practice.

Specimens of existing stages were on view at the lecture.

Miss E. Dora Earthy.—*The health cult of an African tribe, with special reference to child life* (11.0).

Under the auspices of the *Save the Children Fund* this investigation was undertaken during the winter of 1932–33 in the Liberian Hinterland and in Sierra Leone. References are also made to studies among VaLenge children of Portuguese East Africa. Health is of paramount importance to an African, and its quest often supersedes that of food.

Health forms the main subject of prayers to ancestral spirits, hence it belongs to the domain of religion. Children, forming indispensable links in the chain of dead and living, are from birth guarded from hostile influences by various rites, votive offerings and medicines. The author has studied the 'sacrifices' or votive offerings to the spirits for safeguarding the child's health ; and plants used in medicine, the botanical determinations having been made by the Department of Botany of the British Museum.

The tribes studied are the Kisi and Gbande tribes of Liberia, the Mendi of the Sierra Leone Protectorate, the people of Freetown, and the VaLenge of Portuguese East Africa. Brief references are made to special diseases and ailments of child life, with some tentative constructive criticism.

A description is given of a 'sick town' or hospital settlement in the Liberian hinterland, frequented by little-known tribes.

Capt. R. S. Rattray, C.B.E.—*The future of anthropology in Africa or elsewhere* (12.0).

Is this science, which the European has built up around African and other races under the name of Anthropology, destined in the future to be regarded by the subjects of these scientific investigations as just so much interesting archæological data concerning their own dead past ?

Alternatively : Will these peoples come to recognise anthropology as something which has been a living vital factor in shaping their own destinies ?

The answer to these questions would seem largely to depend on two things :

(*a*) Whether the European can, before it is too late, enlist the whole-hearted interest and co-operation, in his anthropological experiments, of the more highly educated members of such communities ;

(*b*) Ability and understanding to discriminate—among the mass of data which we have now accumulated—between what is, and what is not, vital for the attainment of the object which we have in view.

This object may perhaps be defined as the retention of the particular genius and individuality of the races concerned.

Afternoon.

Mr. J. H. Driberg.—*African ancestor worship : a new view* (2.0).

It is maintained that the attitude of Africans towards their dead does not involve a religious cult and that the relationship between the living and the dead is entirely a secular one. There is abundant evidence that for two generations after death the dead continue to function within the organisation of the tribe without any substantial change in social estimation.

Their theory of the soul and of reincarnation, which may take two forms dependent on the social pattern of the community and originating in two distinct types of cross-cousin marriage, partly determines the attitude towards the dead, which is elaborated also by a teleological concept of Elysium which is not necessarily at variance with the theory of reincarnation. It is shown that the evolution of hero-cults and divinities is an exceptional feature of the ancestral organisation, emphasising its secular character rather than pointing to a supposedly religious basis. This view necessitates a revision of the terminology descriptive of the African attitude towards the dead.

Dr. B. S. Guha.—*The racial types in the population of India* (3.0).

The paper embodies the results of the special anthropometric inquiries carried out in 1930–34 on behalf of the last census operations of India, during which the greater part of the country was visited and measurements were taken on nearly 4,000 individuals. The anthropometric data were statistically analysed by means of Prof. Karl Pearson's Coefficient of Racial Likeness, and the results obtained disclose the absence of marked morphological differences between the Brahmins and the upper caste population, whose basic element appears to be Mediterranean, and over which have superimposed (*a*) an Alpine-Armenoid strain in Western India and Bengal, probably entering India at a very early period, as the recent skeletal finds at Harappa would appear to indicate, and (*b*) a proto-Nordic element with the Aryan invasion of North-Western India.

The aboriginal tribes show a definite negrito strain whose remnants are still to be found among the Kadars of the Perambicullum Hills of Cochin. The Mongoloid influence is conspicuous in the territories bordering on the Himalayas and the hills along the eastern frontiers of India.

Prof. Agnes C. L. Donohugh.—*Social sanctions and social restraints in native African society* (4.0).

Friday, September 7.

Dr. J. F. Tocher.—*The services of Francis Galton and his school to physical anthropology and eugenics* (10.0).

Francis Galton, a frequent contributor to the proceedings of the British Association, was President of Section H in Aberdeen in 1885. In his Presidential Address he proved, by the principle of correlation which he had then recently discovered, that heredity could be quantitatively measured, using stature as an illustration. He concluded by saying: 'When heredity shall have become much better and more generally understood than now I can believe that we shall look upon a neglect to conserve any valuable form of family type as a wrongful waste of opportunity. The appearance of each new natural peculiarity is a faltering step in the upward journey of evolution over which, in outward appearance, the whole living world is blindly blundering and stumbling, but whose general direction man has the intelligence dimly to discern and whose progress he has power to facilitate.' By inventing the calculation of correlation, so fully developed by Pearson and his school, Galton placed anthropology upon a sound scientific basis. Galton is the Faraday and Pearson the Clerk Maxwell of anthropology. Since Galton's day a large mass of data bearing upon man's physical and psychical characters has been submitted to statistical analysis with fruitful

results. In Scotland the mixed character of the population has been demonstrated by these quantitative methods now in common use in anthropometry. It is well known that Galton founded the science of national eugenics. He demonstrated that mental and moral as well as physical characters were inherited and therefore that humanity was capable of improvement through conscious selection. In striking contrast to some attempts at race improvement to-day, he held that no hasty or ill-considered method can be thrust on any community. Race improvement in Britain has been helped by legislation and by the effect of public opinion, particularly with regard to social conditions and material well-being. The improvement has arisen through recognition of the fact that environment is a factor in life. But Galton and Pearson have shown that nature is a more powerful factor than nurture. Institutes and societies for race improvement have been established in America and on the Continent, including Russia. Galton defined eugenics as 'the science of those social agencies which influence mentally and physically the racial qualities of future generations.' Until we know more fully than we know to-day what those influencing agencies are, we can do little to eliminate the cave dweller propensities in man which are so rampant in Europe to-day. Galton looked forward to the day when conscious selection for race betterment would be sanctioned by the State, supported by public opinion. One has only to study the *Annals of Eugenics* and other publications of the Galton Laboratory, and the great work of Pearson and of Fisher, his successor, to see that progress has been made in our knowledge of man's past and without conscious selection, his likely future. Material has been provided which should be studied by those at the helm of the State.

Dr. J. Graham Callander.—*Prehistoric archæology in the North-east of Scotland* (11.0).

The north-eastern part of Scotland occupied by the counties of Aberdeen, Banff and Kincardine is particularly rich in monuments and other remains of prehistoric man. In spite of this, and although many extensive collections of relics have been gathered from the area, its antiquities, with the exception of two or three classes, have never been systematically described, and no sustained excavations of the monuments have been carried out and published as have been done in some parts of England. Proof of the occupation of the district by Neolithic man is to be found in the relics left and in a few long cairns erected by him. Many Bronze Age monuments survive; numerous graves containing pottery have been brought to light, and a fair representation of weapons, tools and ornaments of the period have been recorded. The district is famous for its stone circles, that with the recumbent stone being confined to this part; more than two hundred have been found in Aberdeenshire alone. There seems to have been at least one early crannog in Loch Kinord. Earth-houses can be seen in the valleys of the Don and Dee, being very numerous in the neighbourhood of Kildrummy. Good examples of hill forts exist on the Barmekin of Echt, the Hill of Barra and the Mither Tap of Bennachie. Of vitrified forts, two of the finest are located on the Hill of Dunnydeer and the Tap o' Noth.

Miss Ailsa Nicol Smith.—*Material culture as an introduction to social culture* (11.30).

Material culture is a valuable approach to the individual and social life of a people, and therefore is of great practical value to the fieldworker.

Costume for this purpose is especially instructive. This is examined under four headings—ordinary, festive, special, and ritual—and is preceded by a brief sketch of the islands and their inhabitants. Ordinary attire is a guide to the character of individuals and a gauge to the environmental conditions of the group. Special occasions have special costume. In secular festivities the æsthetic sense of the individual finds expression, and on ritual occasions that of the society as a whole. Costume is intimately connected with marriage and widowhood. Ritual costume contributes profoundly to religious sentiment and has useful sociological functions.

Mr. K. H. Jackson.—*The Gaelic Shanachies and some of their lore* (12.0).

The *seanachaí*, anglicised ' shanachy,' is the centre of folk-culture, the village entertainer, preserver of local traditions and beliefs and teller of folk-tales, in the Gaelic districts of Ireland and Scotland ; he has a large repertoire of folk-tales of all kinds, many of which have been distributed throughout Gaeldom by travelling people and handed down by the shanachies.

Beliefs in the supernatural preserved by the shanachies : the malevolent hag (*cailleach*), not a witch ; the evil spirit (*sprid*) ; the enchanted seals which speak ; the mermaid, *piast*, *Ion craois*, leprechaun, etc.

Fairy beliefs : an early type is the *sídhe*-people or *Tvatha Dé Danann*, living apart in burial-mounds but engaging in love affairs with mortals ; a modern tale of this kind. They are now mostly prophetic visitants, whence the modern ' banshee.' The early belief in *Tír na nÓg*, ' the Land of the Young,' and the theme of the wonder-voyage thither ; modern survivals. The *daoine maithe*, fairies of the ordinary European type. Suggested explanation : *Tír na nÓg* is the celtic otherworld, and the *daoine maithe* and *sídhe*-people are perhaps pre-celtic ancestor-spirits, the second evolved from the first. But the *sídhe*-people seem to include certain celtic gods. How far all these beings are really believed in by the folk.

Afternoon.

Prof. V. Gordon Childe.—*The arrival of the Celts in Scotland* (2.0).

At Old Keig (Aberdeenshire), Covesea (Morayshire) and Jarlshof (Shetland) flat-rimmed pottery resembling English Hallstatt wares has been found associated with Late Bronze Age objects of Britannico-Hibernian type. In Shetland an earth-house was connected with this complex. It is due to new settlers, though these were undoubtedly mixed with the older native populations. These Late Bronze Age invaders are the only people to whom the Celtic name of Orkney can be attributed as early as the fifth century B.C. Their pottery is allied in a general way to that of All Cannings Cross in Wiltshire and Scarborough in Yorkshire, and recurs in the Western Isles and in North Ireland. The precise origin of the invaders cannot be determined. But if there were Picts in Ireland speaking a Celtic language, this culture common to the Far North, Aberdeenshire and North Ireland has a good claim to be called Pictish. To it may belong, besides the earth-house, also stone cups with handles, which have a different distribution to the broch relics.

A contingent of cognate people mixed with other elements from Yorkshire may have reinforced the Bronze Age population of the Lowlands and been responsible for the first settlements on Traprain Law and other hill-top towns. Their pottery is rather more closely allied to that from Heathery Burn Cave, Co. Durham, and Eston Nab, near Middlesbrough, than to the pure Scarborough Hallstatt, but such Hallstatt elements may be admitted.

The transition to the Iron Age was gradual here. The parade objects from the Lowlands belong stylistically to the Arras school of Yorkshire and must have been the property of chieftains derived from the Parisii who settled there. Whether such chieftains led the Late Bronze Age contingent to Traprain Law or arrived later is still uncertain.

La Tène Celts coming direct from the continent across the North Sea and landing round the mouth of the Tay and on the Moray Firth must be responsible for the erection of Gallic and vitrified forts which have no parallel in England. They introduced a fully fledged iron industry and were the only people in Scotland to preserve the Celtic fashion of wearing safety-pins. They arrived with a culture still in the La Tène I stage and therefore before 200 B.C. The Gallic forts and most vitrified forts (Duntroon, Dunagoil, Finavon) were abandoned before the Roman period.

The little stone forts of Galloway, Bute and Argyll as well as the galleried duns and brochs constitute a group distinguished by their fine masonry from the earth-houses and Bronze Age villages. All are so small that they cannot have been villages or tribal refuges, but rather the castles of a chieftain with his retainers. Their distribution, agreeing significantly with that of the 'neolithic' chambered cairns, indicates a colonising movement (doubtless in several waves) up the west coasts. The brochs and contemporary dwellings of the subject population (group 1) and caves in the castle-area of Galloway and Bute have yielded a series of relics distinctive of the Glastonbury complex of south-west England. And the architecture of the castles has its nearest parallels in Cornwall. The castle-lords would then be Brythonic Celts arriving from that quarter. They must have superseded the chiefs of group 3 in Bute and Argyll and subjugated group 1 in the Far North, but not in Aberdeenshire.

The crannogs have yielded no relics distinctive of the Glastonbury complex, and cannot therefore be connected directly with the crannogs of Somerset. But pile-dwellings had been established in Yorkshire by Hallstatt folk. And a remarkable bridle-bit from Lochlee is an early derivative of the Arras bits. The crannogs must therefore have been built by refugees from Yorkshire who arrived before A.D. 100—how much is uncertain.

Rev. Dr. A. B. SCOTT.—*The historical sequence of peoples, culture, and characteristics in Scotland from 400* B.C. *to* A.D. *950* (2.45).

The correct historical sequence of the Celtic peoples, culture, social habits, and political organisations in what is now Scotland. The trend of the Celtic migrants generally, and the trend in the British Isles. The Celts who crossed to Ireland by way of Britain. Those who settled in Ireland direct from the continent of Europe. The mass-divisions of the Celts (1) in Britain, (2) in Ireland; and their locations. The first emigration of Iro-British Celts towards what is now Scotland. Where they settled. The social and political effect of their coming. The transportation of southern British Celts into what is now Scotland by the imperial Romans. The counter-movement when imperial Roman power was withdrawn. The Iro-Gaelic and Iro-Dalriad thrust in Argyll. The arrival of the Christian religion. The peoples who received and spread Christian culture. The blood-affinities of the leading Christian teachers in what is now Scotland.

Mr. A. O. CURLE.—*Prehistoric Shetland—the excavations at Jarlshof* (3.30).

Mr. ALEX. KEILLER.—*The Megalithic monuments of the North-east* (4.0).

Saturday, September 8.

Excursion to Barmekin of Echt, Sunhoney Stone Circle,[1] and Midmar.

Monday, September 10.

PRESIDENTIAL ADDRESS by Capt. T. A. JOYCE on *The use and origin of Yerba Maté* (10.0). (See p. 161.)[2]

Mr. A. LESLIE ARMSTRONG.—*The excavation of two Bronze Age burial cairns and associated urn-fields at Grappenhall in the Mersey valley, N. Cheshire* (10.45).

These cairns appear to have been erected upon a dry sandy heath. Subsequent climatic changes caused the deposition of wind-borne sand over a wide area which, at this point, raised the general surface level 3 ft. and entirely buried the cairns. Consequently they were preserved intact until revealed by chance in 1930. Recent acquisition of the site for building enabled a complete examination to be made of both cairns and a large part of their surroundings. Each contained a primary cist burial of cremated remains, early Middle Bronze Age in date, and secondary burials of cremations of late Middle Bronze Age date. A small decorated vessel, suggesting a hybrid form of food-vessel and beaker, and a richly decorated food-vessel, were associated with the primary burials, also leaf and kite-shaped flint arrow-heads. A tri-partite urn enclosed a secondary burial. Excavations outside the cairns revealed in each case an associated urn-field which yielded three tri-partite urns of latest Middle Bronze Age type and numerous deposits of cremated remains.

The early pottery exhibits marked Irish influences, and a study of the Bronze Age antiquities of the locality provides evidence indicating that Warrington was the port on the Mersey through which trade passed between Ireland and the Bronze Age settlements of Derbyshire; also, but in lesser degree, with Yorkshire and the Midlands. The apparent trade routes with these areas were described and discussed.

Rt. Hon. Lord RAGLAN.—*The cult of animals* (11.30).

The religio-sociological aspect of animals, as distinct from the purely utilitarian, may be discussed under eight heads: (1) Totemism. (2) Talking animals. (3) The ceremonial wearing of horns, skins, etc. (4) Lycanthropy. (5) Gods in animal form. (6) Animal sacrifices. (7) Animals as omens. (8) Animals as emblems and symbols.

In all these cases there are human and animal alternatives: (1) Linked clans. (2) The talking animal identified with a man. (3) The wearing of human masks, scalps, etc. (4) Human shape-changing. (5) Gods with both human and animal forms. (6) Human sacrifices. (7) Human beings as omens. (8) Female figures, etc., as emblems and symbols.

We find, however, that real people are never identified with real animals. Even small children do not believe that real animals can talk. The werewolf is a magic wolf, never a real wolf. We find further that in all the eight classes mentioned above there are substitutes which are neither human

[1] A model of this stone circle, by Mr. John A. Gentles, together with some Aberdeen palæoliths, was exhibited in Marischal College during the meeting.

[2] In the absence of the President, the address was read by Prof. H. J. Fleure.

nor animal: (1) A tree or cloud as totem. (2) Talking insects and flowers. (3) People disguised as trees, e.g. Jack-in-the-Green. (4) People changed into a flower or a pillar of salt. (5) Gods in stone, etc. (6) A cake or cup of wine as a sacrifice. (7) Dice or sticks as omens. (8) A cross or a star as an emblem or symbol.

It would seem that all these phenomena are connected, and are the result of a long and complex process of symbolisation—that is to say, the provision of ritually effective substitutes. This is the work of religious philosophers, and has filtered down to children and savages, whose symbolism, whether conscious or unconscious, merely reflects the conventional symbolism of their group.

AFTERNOON.

Mr. K. P. CHATTOPADHYAY.—*The Chadak festival in Bengal* (2.0).

The Chadak *puja* or festival is celebrated at the end of the Bengali new year, in Bengal. It is also found in the Dravidian-speaking tracts of South India. No detailed description of the ceremonial has, however, been so far available in print. This defect is remedied by the present paper.

A detailed knowledge of the festival is important from the point of view of analysis of Indian social organisation and culture. It represents a survival from the pre-Vedic culture in which there was a definite belief in resurrection of the dead person. The friends and relatives helped to bring back the dead to life and joyfully hailed his return with song and dance. The Chadak festival as it is found now can be traced to the older beliefs only through the parallel festivals of Mānda parab in Chotanagpore, and the worship of Dharma or Dharmaraja in Bengal and South India.

A detailed description of the different parts of the ceremonies was given, and the reasons for not discussing their significance at this stage were noted.

Mrs. H. W. ELGEE.—*The Megalithic cult of the eastern moorlands of Yorkshire* (3.0).

In this region Megalithic structures comprise the following types: (1) Monoliths. (2) Rows or Alignments. (3) Parapets or Stockades. (4) Circles. (5) Ovals. (6) Triangles.

They are associated with barrows and cairns, mostly of Mid-Bronze Age, and there is no evidence that any are earlier than the Early Bronze Age. The Triangles, or groups of three stones, are a type hitherto unrecognised. That Megaliths were fertility symbols is to be seen in the prevailing belief of the moorland farmers in the efficacy of rubbing-stones, and in the male and female stone gate-posts of their fields.

Prof. T. F. McILWRAITH.—*The influence of mythology upon the culture of the coastal Indians of British Columbia* (4.0).

Tuesday, September 11.

Mr. JAMES COOPER CLARK.—*An Aztec manuscript known as the Collection of Mendoza* (10.0).

The Aztec manuscript known as 'the Collection of Mendoza' is preserved in the Bodleian Library and was compiled in 1549 by order of Don Antonio de Mendoza, first Viceroy of New Spain, with the intention of conveying to His Majesty Charles V some idea, from native sources, of the history, manners, and customs of the Indians of his lately acquired possession.

The manuscript consists of seventy-one folio pages and is divided into three parts: the first, beginning with the traditional settlement of the Mexicans on the shores of Lake Tetzcuco, contains a list, length of reign, and conquests of the nine successive lords of Tenochtitlan; the second is a copy of the Tribute Roll of Motecuçoma Xocoyotl, whose authority ended with the coming of Cortés in 1519; while the third part illustrates the life of the Indian from the cradle to the grave.

The Viceroy employed a native artist who used his own colours of yellow ochre, indigo, and cochineal, with, of course, their combinations. He was supplied with European-made paper.

The vessel conveying this document to Europe was captured by a French frigate and so, instead of being handed to Charles V of Spain, it was delivered to Henry II of France. In 1553 it came into the possession of André Thevet, the French king's cosmographer, who sold it to Richard Hakluyt for twenty French crowns, and he, dying, left all his books and manuscripts to Samuel Purchas the Elder, who included the Mendoza MS. in his 1625 edition of *Hakluytus Posthumus*; from Purchas it passed to John Selden, who, in turn, bequeathed his books to the Bodleian Library.

Prof. W. C. O. Hill.—*The physical anthropology of the existing Veddahs of Ceylon* (11.0).

Definition of Veddahs; present range, status and numbers; reasons for disappearance; effects of miscegenation; probable fate. Changes since the visits of the Sarasins and Seligmans.

General appearance of the typical Veddah of to-day. Misleading statements of the older writers. New material for study. The living Veddahs. Results of studies on recent skeletons. Recovery of two complete cadavers.

Morphological characters. External characters. Stature; skin; hair; facial characters; limb-proportions; flat-feet; foot-prints. Skeletal characters; skull; spine; comparison with Sinhalese and Tamil. Characters of soft parts; brain, brain-weight; interesting anomalies so far discovered. Relative frequence of similar anomalies in Sinhalese and Tamil bodies.

Summary; affinities of the Veddahs to Indian jungle-tribes, Negritoes and Australians.

Rev. Canon J. A. MacCulloch.—*Folk-lore and archaic magic in the Scottish witch trials* (12.0).

The foundation of all witchcraft, ancient and modern, savage and civilised, is the old and universal belief in *maleficium*, working through magic or with the aid of spirits. In its narrower sense, *maleficium* was believed to be exercised in many different ways—destroying life, causing disease or madness, taking the substance of crops, milk, etc. In later times the witch was often merely a person learned in traditional methods of healing, more or less magical, and all harmless. Yet this was counted as *maleficium*, because she was believed to have been instructed by the devil, as examples prove.

The witch flight, nocturnal assemblies, homage to Satan, etc., may be regarded partly as imaginative elements, partly as the creation of current beliefs, folk-lore, and gossip, codified into a system in the fourteenth century.

In Scottish witchcraft, as depicted in the trials, *maleficium* is the main fact which emerges. Now it was exercised according to the methods of archaic and universal magic. Now it was merely more or less harmless traditional folk-lore. Or it was connected with spirit and fairy lore.

Examples of (1) archaic magic; (2) traditional folk-lore; (3) fairy beliefs.

The Scottish witch was a repository of all kinds of beliefs, which leading questions at the trials occasionally made into a diabolical system. She was probably imaginative. Under suffering or torture she would confess to anything suggested to her. There is no real historic evidence for a witch-cult in Scotland.

SECTION I.—PHYSIOLOGY.

Thursday, September 6.

SYMPOSIUM on *Some recent advances in the physiology and pathology of the blood* (10.0):—

Prof. J. BARCROFT, C.B.E., F.R.S.—*Respiratory function of blood in the fœtus.*

The fœtus presents the problem of an organism which is outgrowing its organisation for supply. This is true, among other things, of the supply of oxygen. The blood emerging from the uterus becomes progressively darker throughout pregnancy, which means a continuous drop in the pressure at which the oxygen is presented to the fœtal blood in the placenta.

The problem which confronts the organism is that of providing a sufficient pressure gradient between the maternal and fœtal blood. The solution lies in a divergence of the dissociation curve of each blood from the normal. That of the mother is displaced ' to the right ' and that of the fœtus ' to the left '—thus creating a gap, so that over a great part of the curve the fœtal blood at a given oxygen pressure is about 25 per cent. more saturated than the maternal. The shift in the maternal curve is due to increased pH, that in the fœtal curve to a specific difference in the hæmoglobin.

The pressure at which the oxygen leaves the placenta in most animals is low; it is further reduced before reaching the fœtal arteries by admixture of the umbilical blood with that from other veins. Consequently the embryo exists under anoxæmic conditions.

Prof. L. S. P. DAVIDSON.—*Nutrition in relation to anæmia.*

Within the past ten years an unparalleled advance in knowledge regarding the relationship of diet to blood formation has occurred, which has been the means of eliminating certain forms of anæmia completely, of bringing under therapeutic control others which were incurable, and of directing attention to forms of anæmia which had escaped notice. Previous to 1926 the cause of pernicious anæmia was unknown and treatment was so unsatisfactory that every patient died. To-day we know that the essential cause lies in a failure of gastric secretion, so that the patient is unable to obtain from his food a principle which is essential for normal blood formation. By the administration of liver, or extracts made therefrom, a sufferer from pernicious anæmia can now lead a normal life.

Of greater economic importance, in view of its extraordinary frequency, is the group of nutritional anæmias due to iron deficiency. Approximately 50 per cent. of infants and adult women of the poorest classes are anæmic. The causes of this deficiency are now understood and accordingly can be

corrected. The principal factors are (1) pregnancy and loss of blood at the periods, leading to increased demands for iron; and (2) an iron-poor diet which fails to maintain adequate reserves to meet such eventualities. Dieto-therapy and the administration of iron-salts rapidly and cheaply cause a remarkable improvement in health, with a corresponding gain in economic efficiency and resistance to disease.

Dr. F. J. W. ROUGHTON.—*Recent work on carbon dioxide transport.*

Since 1928 there have been two new developments in the problem of carbon dioxide transport by the blood:

(1) It has been found that the red blood corpuscles (but not the plasma) contain large amounts of a powerful enzyme, carbonic anhydrase, which catalyses both phases of the reversible reaction, $H_2CO_3 \rightleftharpoons CO_2 + H_2O$.

(2) Small amounts of carbon dioxide have been shown to combine directly with the hæmoglobin of the blood to form compounds probably of a carbamino type, e.g. $HbNH_2 + CO_2 \rightleftharpoons HbNHCOOH$ (hæmoglobo-carbamic acid), and possibly of some other type as well. The tendency to form carbamic compounds is far more marked in the case of reduced hæmoglobin than in oxyhæmoglobin.

These two discoveries mean that our previous views require some resetting. An attempt will be made to give an up-to-date picture of the operations which confront the CO_2 molecule from the earliest stage, i.e. its liberation in the course of metabolism, right up to the final stage, viz. that of liberation into the expired air.

Dr. G. A. MILLIKAN.—*Recent work on the hæmoglobins.*

The family of the hæmoglobins is becoming daily more diverse. Different animals may possess hæmoglobins with molecular weights ranging all the way from 17,000 (Chironomus) to several million (Arenicola). And even in the blood of a single animal, there is now evidence that there may be two or more hæmoglobins differing from each other in iso-electric points or in resistivity to denaturation. Recent spectroscopic work shows, moreover, that the hæmoglobin inside the corpuscle may differ markedly from that of laked blood. Finally, kinetic experiments show that there may be large differences in the reactive properties of hæmoglobin depending upon whether it has very recently been oxygenated or reduced.

Muscle hæmoglobin has been shown to possess an oxygen dissociation curve of the simple hyperbolic type, interpretable on the classical Hüfner theory. For pigments showing the commoner sigmoid curves, new kinetic evidence, as well as the older molecular weight data, overwhelmingly favours the ' step-by-step ' intermediate compound hypothesis as against the ' all-at-once ' theory.

AFTERNOON.

Visit to the Rowett Research Institute.

Friday, September 7.

JOINT SYMPOSIUM with Section M (Agriculture) on *Nutrition in relation to disease* (10.0):—

Dr. J. B. ORR, D.S.O., F.R.S.

A short non-technical account is given of the broad principles of nutrition in relation to disease which have been established in the last twenty-five

years. The bearing of this recently acquired knowledge on public health and on the elimination of disease of farm animals is discussed.

Reference is made to the results of some recent investigations which indicate that nutrition as determined by diet is now probably the most important factor affecting the health of the community.

It is suggested that the present generally accepted standards of health are too low. If the necessary measures could be taken to ensure that every member of the community had a diet which was fully adequate for health, the next generation would be of better physique and free from much of the disease and indefinite ill-health which afflict the present generation.

Prof. J. J. R. Macleod, F.R.S.

The time-honoured belief that health is closely linked with diet, and that improvement of the state of bodily nutrition, by dietary control, is an important factor in the treatment of disease, has received ample support by recent research. Vitamins and minerals, no less than calories and protein units, are essential in the diet, and various definite diseases have been shown to be the result of deficiencies in the former. Since most of these deficiency diseases occur in the lower animals as well as in man, it has been possible to determine the exact nature of the deficiencies responsible for their occurrence, but the problem awaiting investigation is to determine to what extent more general diseases in man may be similarly related. There is evidence to show that diabetes, anæmia and goitre are nutritional diseases, and it is probable that other types of illness are due to faulty dietetic habits. But much careful work, in which both laboratory workers and doctors collaborate, will have to be done before these problems can be solved. That such investigations will be of benefit to mankind is evidenced by the discoveries which have been made during recent years in the field of animal nutrition.

Dr. May Mellanby.

Dental decay (caries) is almost universal in civilised countries.

Carefully controlled investigations on man and animals during the past fifteen years have resulted in a new outlook in dental science.

Faulty nutrition, especially in early life, is the cause of defective structure, this in turn predisposing towards caries. Teeth are commonly imperfectly formed, hence the high incidence of decay; in a microscopical examination of 1,500 milk teeth, 93 per cent. of those very defective were decayed as compared with 20 per cent. of the perfect.

For good structure diet of mother during pregnancy and lactation, and of child after weaning, must include abundant calcium and phosphorus (of which teeth are largely composed), and the specific calcifying-factor, vitamin D (egg-yolk, cod-liver oil, milk, etc.). Cereals contain anti-calcifying toxamins; their consumption should be limited.

Vitamin D helps to prevent and to arrest caries even in imperfect teeth (Sheffield and Birmingham investigations).

Beautiful teeth almost caries-free found in:—

(1) Eskimos; vitamin D from blubber.
(2) Natives of tropics; vitamin D through exposure of whole body, especially while young, to ultra-violet rays of the sun. Breast-feeding is prolonged.

When these peoples adopt the diet and clothing of civilisation their teeth

deteriorate rapidly, *vide* Eskimos of trading stations, negroes in New York. Heredity is therefore not a fundamental factor.

The incidence of pyorrhœa is reduced by giving abundant vitamin A (liver oil, green vegetables, etc.), especially during development.

Prof. S. J. Cowell.

Malnutrition in the sense of faulty feeding leads to disease, and disease leads to malnutrition in the sense of the production of a state of imperfect nutrition. It is therefore often difficult to decide how far wrong feeding is responsible for any observed case of poor physical development or lack of bodily fitness. Faulty diets lead to disease in a variety of ways. In some instances a deficiency of definite inorganic or organic substance in the food may cause a recognisable train of symptoms which may be cleared up by making good the deficiency. But similar deficiencies exerting their effects in early life may lead to faulty development of tissues which cannot subsequently be restored to their perfect state, thus predisposing to disease in later life. Other diseases may arise from some inherent or acquired incapacity of the body to deal in the normal way with essential food factors actually supplied in the diet. When it is remembered that foods in common use may be sources of positively harmful substances as well as be deficient in beneficial substances, it is obvious that the construction of ideal diets requires greater knowledge than is available at the present time.

Dr. H. H. Green.—*Nutrition in relation to diseases of the larger domesticated animals.*

Amongst the economically important domesticated animals vitamin deficiency diseases are rare, even in animals in which they can be produced experimentally. In pigs reared under intensive conditions disorders arising from deficiency of vitamins A and D have been reported, but no avitaminosis has yet been reported in grazing animals however poor the pasture.

On the other hand, mineral deficiencies are of enormous economic importance throughout the world, and on millions of acres of grazing land throughout the Empire the mineral content of the pasture, most commonly the phosphorus content, is the limiting factor in stock raising. Aphosphorosis of cattle and sheep is a recognised syndrome somewhere in every continent, although it may vary in its manifestations from severe osteomalacia and rickets, through reduced fertility occasioned by protective cessation of ovulation, down to slow development and poor economic returns in relation to the food supply apparently available. Indirectly linked to nutritional deficiency may come diseases of quite unexpected immediate origin, e.g. acute botulism in cattle displaying the osteophagia characteristic of aphosphorosis.

Deficiencies of phosphorus, calcium, iodine, iron and copper in various parts of the world are discussed.

Special attention is drawn to the different physiological reactions of different species of animal to the same type of dietary deficiency, and to the different etiology of diseases which present the same pathological picture. Thus the bovine develops rickets and osteomalacia on certain types of phosphorus deficient pasture upon which the equine remains apparently healthy. The equine develops osteodystrophia fibrosa upon a calcium-phosphorus ratio which only induces slight osteoporosis in the bovine ($CaO : P_2O_5$, 1 : 3). The pathological picture of extreme aphosphorosis in the bovine is the same as D-avitaminosis in the human subject and in

the pet dog. The pathological picture of hyperphosphorosis in the horse is similar to that of Recklinghausen's disease in man, a disease in which parathyroid dysfunction plays a part. Cattle, sheep and horses remain in good health for years on a ration which would bring a guinea-pig down with scurvy in a month. Weaned cattle are relatively independent of external supplies of all the known vitamins, and can grow to healthy maturity on a ration which would at once induce growth failure and various avitaminoses in laboratory animals. Disabling disorders of horses may occur on a type of mineral imbalance which the human subject seems able to tolerate.

Health or disease is thus not only a question of the composition of the ration, but also of the species of animal; perhaps also of the number of generations over which the ration is fed.

Dr. D. Robertson.—*The association of nutrition and helminth infestations.*

Experiments bearing on the influence of the plane of nutrition on the helminth infestations of animals which have been carried out in different parts of the world are discussed and the possibility of reducing losses from parasitic disease by suitable feeding are considered.

Evidence that the degree of parasitic infestation in lambs has a direct bearing on the nutritional state of the animal, which has been obtained as a result of a survey which is in progress in Scotland, is reported.

Experiments carried out at the Rowett Institute on the effect of nutrition on the susceptibility of sheep to worm invasion are described, and the total evidence that the nutritional condition of an animal is closely related to its susceptibility to helminthic infections is summarised.

Discussion. (Dr. H. E. Magee; Prof. T. H. Easterfield; Dr. Scott Robertson; Dr. Ivy Mackenzie; Rt. Hon. W. Elliot, P.C., M.P.; Sir F. Gowland Hopkins, Pres. R.S.)

Monday, September 10.

Mr. T. W. Adams and Dr. E. P. Poulton.—*A new study of heat production in man* (10.0).

It has been shown that the heat output in man cannot be correctly calculated by multiplying the oxygen by a factor depending on the oxygen and the respiratory quotient. Consequently the R.Q. does not indicate the proportion of carbohydrate and fat being burnt [*Proc. Roy. Soc. Med.*, **26**, 1591 (1933)]. The alternative theory is advanced that under basal (standard) conditions the carbon dioxide measures the amounts of carbohydrate and fat burnt in a fixed proportion at an R.Q. of about 0·8, and that a rise or fall in R.Q. means a partial reduction or oxidation of fat or carbohydrate. The proof of this theory depends on—

(*a*) greater constancy of carbon dioxide than oxygen;
(*b*) high correlation of carbon dioxide and heat;
(*c*) if oxygen represents combustion, it is difficult on theoretical grounds to see how carbon dioxide can result from a partial reduction of carbohydrate;
(*d*) the correlation of oxygen and heat is not so satisfactory, since the theoretical limits of variation of oxygen are smaller.

On this theory the following conclusions are drawn :

(1) In fasting subjects pure fat is burnt.
(2) Mild exercise tends to the greater burning of carbohydrate.
(3) Fever may tend to the greater burning of carbohydrate.
(4) If carbon dioxide, taken as a measure of basal metabolism, is compared with body weight, there is a definite change in direction of the curve between two and four years. A similar change occurs at this age period in the relation of height and weight.
(5) Basal metabolism (CO_2) depends on the weight and very little on the height of the individual.
(6) In obese and thin subjects the relation, basal metabolism : weight, is not far removed from the normal ; fasting lowers the metabolism more than the weight.
(7) The low specific dynamic action of carbohydrate compared with protein is due to heat absorption resulting from partial reduction towards fat.

Dr. MARIE C. STOPES.—*Some points in the technique of contraception depending on temperature* (10.25).

Records of temperatures of the *cervix uteri* as contrasted with oral and anal temperatures considered ; the function of grease in contraceptive technique ; difficulty of practical problems raised by the narrow margin between cervical and atmospheric temperatures at certain times and localities ; unsatisfactory nature of current attempts at solution due to ignoring the essential melting points involved ; cumbrousness of some current devices, e.g. transit in vacuum flasks ; a simple but effective vehicle devised ; further desiderata discussed.

PRESIDENTIAL ADDRESS by Prof. H. E. ROAF on *Normal and abnormal colour vision* (10.45). (See p. 169.)

Dr. F. W. EDRIDGE-GREEN, C.B.E.—*The theory of vision* (12.15).

It has been proved that the cones of the retina are the percipient elements for vision, and direct stimulation by light has been assumed without any evidence. Direct stimulation of the colourless transparent cones is against all photochemical laws, as no effect can be produced by light unless it is absorbed. Stimulation of the cones takes place through the photochemical decomposition of the liquid surrounding them, sensitised by the visual purple. The rods are not percipient elements but control the visual purple. This theory explains every known fact of vision, including numerous facts inexplicable on any other view.

Dr. IVY MACKENZIE.—*The physiological basis of visual sensation* (12.35).

The function of the anatomical substratum of human vision may be considered from the point of view of physics or of biology or of psychology. Physical considerations predominate in the analysis of events in front of the retina ; psychological interpretation plays a large part in the events behind the areæ striatæ, while the processes between the retinæ and areæ striatæ lend themselves to anatomical and physiological observation. The visual pathways between the retinæ and areæ striatæ comprise the basis of visual sensation as distinct from perception. This neural compendium is of bilaterally symmetrical conformation, and a knowledge of its constituent parts provides the main standard of reference in localisation of brain disease.

In lower vertebrates its bilateral symmetry is related to the symmetrical character of somatic movement. The tendency to right-handedness in the human subject reveals a difference between the right and left sides of the brain in respect of participation in visual reaction—but only when vision is concerned with perceptual reactions.

Afternoon.

Prof. John Tait and Dr. W. J. McNally.—*Some features of the physiology of the frog's utricular maculæ* (2.45).

Two types of operation, each extralabyrinthine, have been used. Firstly, the nerve twig of supply to each utricular macula has been divided without damage to the nervous connections of any of the other receptors. Secondly, the nerves to all the labyrinthine receptors except the utricular maculæ have been put out of commission.

The first kind of operation produces little conspicuous disability. Not only can the frog crawl, leap and swim, but it retains its body-righting reaction as well. The main disabilities are incapacity to land properly after free fall from a height, absence of compensatory adjustments of the (blinded) animal to slow tilt of the substratum, and a fine head tremor that accompanies all movement.

A frog subjected to the second type of operation shows grave disorder. During any attempted movement it is subject to distressing bodily pendulation of a massive kind. The animal retains its compensatory reactions to slow tilt. By quick tilt, on the other hand, it is at once impelled to execute an active movement of an opposite kind, whereby its balance is more than ever imperilled.

Analysis indicates that the utricular otoconia are not simple weights that slip in a downhill direction on tilt of the head, but that they resemble buoys in being heavier at one end than the other. By means of a model one may show how such a conception of their structure fits all the available facts.

Prof. John Tait.—*Evolution of voice in vertebrates* (3.15).

In terrestrial vertebrates intercommunication by means of sound involves (on the productor side) the respiratory apparatus with its supply of air. We tend to think of the emitted vocal signals as being air-conveyed, but fishes use water as the medium of communication. So does a frog, whose croaking apparatus is designed more for under-water than for above-water transmission. The croak of the frog, best studied with a hydrophone, involves no loss of its contained air. Its mouth-sacs are amplifiers. The nasal sacs situated on the front of the skull of a whale are presumably similar amplifiers for an animal signalling below water with a self-contained volume of air.

It is suggested that in its early origin the air-bladder of fishes subserved vocal as much as respiratory requirements. It happens for physical reasons that an enclosed volume of air, thrown into vibration by any means, is an excellent mechanism for production of low-pitched sounds. Having gulped air, certain early fishes apparently 'experimented' along these lines. Eventually a special pocket, the air-bladder, developed in close relation with the motor apparatus of respiration. This view is based on the frequency with which different kinds of fishes, e.g. Cypriniformes, Dipnoi, not to mention others, have a sound-producing air-bladder. Terrestrial vertebrates came of an aquatic stock possessed of a vocal air-bladder.

Prof. J. A. MacWilliam, F.R.S.—*The regulation of the heart-beat and blood pressure, with special reference to the effects of posture* (3.45).

Postural effects on the circulatory system are related to :

(1) Attitude, *per se*.
(2) Tonic muscular contraction involved.
(3) Stretching and compression of certain muscles.

Quite different mechanisms are concerned in the pulse-rate differences in standing, sitting and lying—the carotid sinus reflex on changing from sitting to lying, and the positions of the thighs in standing and sitting. The buffer nerves and especially the carotid sinus reflex play a very important part. This reflex varies greatly in responsiveness from time to time and with motor effort, emotion, etc. ; several other vascular reflexes are closely associated, but some others are not. Heart rate and blood pressure do not necessarily show parallelism with the carotid sinus reflex ; there are other factors influencing the control by the central nervous system, including impulses from the lower limbs, skin, abdominal viscera, etc., apparently independent of the buffer nerve mechanism. Afferent impulses from the vascular circuit in the lower limbs are important. Several postural vascular responses, absent while the trunk is horizontal, become operative when the upper end of the body is raised 30° or more from the horizontal plane. Great changes in blood pressure result from strong, extensive, tonic muscular contraction, as in standing with the knees bent, also during some dreams with emotional disturbance, sense of motor effort, nightmare, etc.

Col. C. J. Bond, C.M.G.—*The 'Arneth' count* (4.15).

In this communication evidence was presented to show that increase in the number of nucleus lobes in the polymorph leucocyte is dependent on the activity previously exercised, rather than on the age of the cell. This activity can be stimulated in various ways : (1) by incubating blood in a glass cell at body temperature ; (2) by allowing the leucocytes, so incubated, to return to the rounded-up resting condition ; and (3) by re-incubation of the same cell. Under such conditions it will be found that the cells in the incubated and re-incubated slides will show, on the average, a higher number of lobes per cell than the cells in the film obtained direct from the blood stream or in the resting condition. The living pus cell may be regarded as a cell which has exercised much activity. It has emigrated through the capillary wall, it has wandered through the tissues, or on to the surface of a mucous membrane or wound. It may have ingested disease organisms or pigment particles such as carmine or indigo during incubation. It is, therefore, of interest to find that living active pus cells contain a larger number of lobes per cell than the white polymorph blood cells obtained from the blood stream of the same individual.

The results of these incubation and feeding experiments were shown in graph form by charts illustrating the number of lobes in 100 cells in the case of blood films, incubated blood, resting cells, and re-incubated cells, from the same individual; also charts showing the relative increase in number of nuclei in pus cells, as against polymorphs from the blood stream, and also in cases of macrocytic or pernicious anæmia. The suggestion was made that the increase in number of lobes per cell in the latter case was associated with the increased work and activity exercised by the smaller leucocyte and polymorph population in such cases.

Tuesday, September 11.

SYMPOSIUM on *Food preservation* (10.0) :—

Mr. A. LUMLEY and Mr. J. PIQUÉ.—*Some problems arising in the preservation of fish as food.*

Broadly there are five ways of preserving fish : dry salt curing, wet salt curing or pickling, smoke curing, canning, and refrigeration. The first three appear to have been practised since time immemorial, the fourth for little more than one hundred years, while refrigeration is a modern development, though there is some evidence of the employment of cold by the ancients.

To-day each method of preservation has its concomitant group of problems to many of which scientific research is being applied. Those associated with the three types of curing and with canning are briefly referred to.

The authors then deal with refrigeration, distinguishing between modes and applications. In conclusion, possibilities of certain applications are considered from a commercial standpoint.

Dr. T. MORAN, Dr. G. A. REAY and Dr. E. C. SMITH.—*Temperature and the post-mortem changes in muscle proteins.*

Control of temperature is probably the most powerful weapon available in the technology of food preservation. In the case of spoilage by micro-organisms this is a commonplace, but in the matter of the maintenance of the fresh quality of the material the effects due to temperature of storage are more subtle. However, recent research on fish and meat has led to a much clearer understanding of the changes in appearance, tenderness, texture and flavour which these foods undergo during storage at different temperatures. Many of the changes that take place can be related to alteration in the state of the proteins.

A brief account is given of the nature of the proteins in muscle and their solubility relations under different conditions. These results are discussed in relation to the fundamental problem of the 'life-death' change as well as the practical problems of the successful chilling, freezing, curing and storage of dead animal tissues.

Dr. F. KIDD and Dr. C. WEST.—*The storage and transport of fresh fruits.*

The large scale on which operations in the storage and transport of fresh fruits are conducted in modern practice. Types of scientific problems which arise.

Problems with regard to wastage. Types of disease causing wastage and some recent advances in the study of their origin, development and control.

Problems connected with the control of temperature and other conditions in bulk storage. Economic compulsion towards larger and larger units and closer packing ; biological necessity for even conditions of temperature and ventilation throughout.

Problems connected with study of the growth, maturity and senescence of fruits. Recent advances in the analysis of the ontogenetic sequence in terms of respiratory activity and molecular components of the system in the case of the apple. Factors affecting the rate and character of this sequence after the fruit is gathered. Successful application of recent

discoveries to commercial storage practice, in obtaining longer storage life and better quality; gas storage. The control of the composition of the storage atmosphere; providing a fruit store with 'lungs.'

Dr. C. H. Lea and Dr. J. A. Lovern.—*On certain aspects of the biochemistry of animal fats.*

The development of an unpleasant odour or flavour in the fat frequently determines the storage life of a foodstuff.

Keeping quality in a fat is determined by its composition and storage environment. The factors influencing composition have been studied particularly with regard to fish oils. The type of fat deposited is shown to depend upon the diet, the environment (salt water or fresh), and sometimes the species.

In the species so far studied the mobilisation of depot fat appears to be a non-selective process, but fat is selectively transferred to the developing gonads. Further, the theory of desaturation in the liver, which has been advanced in the case of mammals, is not supported from results from fish.

Recent work has led to a clearer distinction between the parts played by the action of tissue enzymes, by micro-organisms, by atmospheric oxidation, and by the absorption of foreign odours in promoting deterioration of fats.

Low temperatures, reduced atmospheric humidity or the presence of carbon dioxide retard tainting of fats by micro-organisms.

Oxidation can be followed quantitatively by determination of peroxide oxygen or of aldehyde oxidation products, the former method serving also as the basis of a method for estimating susceptibility. The oxidation of fats is accelerated by light and retarded by antioxidants.

Some practical applications of recent discoveries.

SECTION J.—PSYCHOLOGY.

Thursday, September 6.

Mr. D. Kennedy-Fraser.—*The immature reaction to number of older feeble-minded boys* (10.0).

A group inventory test of addition, subtraction and multiplication applied to older feeble-minded boys aged thirteen to sixteen revealed that they were slower, less accurate, more subject to typical errors and more prone to use primitive methods than normal boys of the same or a younger age. Finger-counting was especially noticeable. An individual diagnostic test exposing m rows of n discs (3×5, 4×6, 5×7, 3×4, 3×3) demonstrated the immaturity of the boys' reactions. A total of 1,000 reactions made by 200 boys gave only 289 multiplicative reactions of the form $m \times n$ and 423 additive types $m + m + m$, while as many as 288 were of the primitive form of counting by units. It is further clear that even where a boy appears to succeed in an ordinary class exercise, an individual diagnostic test may reveal faulty modes of reaction.

Dr. M. E. Bickersteth.—*Bilingualism* (10.45).

Gaelic is the home language of children living in the sparsely populated districts of the Western Highlands and Islands, and they enter school

knowing no word of English. The present investigation was undertaken with the object of discovering the influence of bilingualism on the thought processes of children of Primary School age. Mental tests have been given in isolated schools in the Western Highlands and Islands over a period of ten years. A group of children has also been retested with the Drever-Collins Performance Scale, and the results correlated with those of the 1932 Scottish Mental Survey of Intelligence. Significant factors influencing the results of intelligence tests are ; (1) The conditions of extreme isolation under which the children grow up ; some of the side schools visited for the purpose of the investigation can only be reached by boat, and in favourable weather. (2) The influence, on a young child's mental and emotional development, of a second language, acquired *before* the power of expression in the mother tongue has become effective.

Mr. R. J. Bartlett.—*Association tests with psychotic patients* (11.30).

Tests in free and controlled association were given to 29 psychotic and 14 normal subjects.

The psychotic records vary from an approximation to normal records to those in which words were replaced by phrases the links between which it is difficult, perhaps impossible, to surmise.

With linked free associates large median differences between psychotic and normal records were obtained. In controlled associates the median differences varied from a small amount that is not statistically significant in the case of writing ' words beginning with S ' to a difference 11·5 times its probable error for writing ' opposites.' In the first part of a test resembling Jung's, association times varied from a record with interquartile range 1·2–1·8 sec. and longest time of 2·2 sec. to one with interquartile range of 8·5–16·2 sec. and longest time 53·2 sec. In the second and third parts of the test yet longer times and considerable variation in recovery ability were registered.

Small but significant correlations between physicians' estimates and test scores were obtained, and it is hoped that the work may develop into tests of value in the treatment of patients in securing (1) for the physician, additional contact with the patient's mental difficulties, and (2) for the patient, a renewed contact with his rational past.

Prof. D. Katz.—(i) *Dissolution of the family in hens* (12.15).
(ii) *Localisation of sound by dogs.*

Afternoon.

(Section meeting in two divisions.)

Division 1.

Discussion on *Perseveration* (2.0) :—

Dr. Ll. Wynn Jones.—*Introduction.*

Manifestations of perseveration may be classified in various ways, e.g. as affective, conative, ideational, sensory, or motor aspects of mentality. The study of the interrelation between these forms of perseveration has not received adequate attention.

Investigators agree in finding evidence for a common factor in the motor tests which may, therefore, serve the important function of supplying

reference values. Thus sensory tests such as Wiersma's colours test and ideational tests such as Müller's memory test may be studied by means of the tetrad criterion, and the results could be analysed in the light of Spearman's Law of Inertia.

Experience with the motor tests shows that the following factors need attention : (1) The lack of self-control, a factor whose relation to perseveration is not definitely known. (2) The relation of general mental ability to the activities operative in each test must be ascertained. (3) Differences in speed of writing may affect the measure of perseveration which has been adopted. (4) Consequently there is the need of choosing for each test a function of maximum potency as measure of perseveration. (5) Lack of standardised tests. It is further suggested by a preliminary investigation with siblings as subjects that it may thus be possible to determine whether any of the alleged manifestations of perseveration are subject to hereditary influences.

Dr. W. Stephenson.

Dr. P. E. Vernon.—*Perseveration tests and the concept of levels in temperament testing.*

Temperament is generally conceived as an organised system of general traits and instinctive drives, a kind of hierarchy in which the ' lower level ' specific activities subserve the ' higher level ' functions. An individual's higher traits are best revealed in situations which are to him meaningful and important ; hence a study of his lower-level sensory and motor processes tells us very little about him that is significant. This point of view is fully borne out by a large body of experimental evidence from the results of various tests representative of different psychological levels. Perseveration tests seem to be akin to other simple sensory and motor tests which, while highly accurate and objective, are extremely specific (i.e. their intercorrelations with one another are very small), have little meaning for the individual subject, and show very poor predictive validity in respect of any higher-level trait.

Rev. Dr. J. Leycester King, S.J.—*The relation between perseveration and complex-synthesis.*

Theissen (1924) and Ewald (1929) established the existence of individual differences in what has been called ' complex-span.' Individuals with wide complex-span are able to group many single elements into a new complex mental whole, while those with narrow complex-span are only successful in building up small mental complexes. A review of these facts in the light of Lindworsky's theory of mental resonance led to the prediction that narrow complex-span should correlate positively with high perseveration.

An experimental research undertaken in confirmation of this prediction showed that a correlation does in fact exist between complex-span and motor-perseveration as determined by writing tests.

Furthermore, the experimental results provided interesting indications as to the conditions under which perseveration may either favour or hinder the learning process. When entirely new material is to be learnt, weak perseverators are more successful than strong perseverators ; when, however, the material to be learnt was composed of elements already learnt in a different order or combination, strong perseverators were found to be more successful than weak.

Failure was experienced with certain P-tests which had proved successful in the hands of other investigators. These tests are criticised from the point of view of technique.

Division 2.

Mr. H. Binns.—*A measure of tactile sense* (2.0).

A measure which, it is suggested, is of universal application, required a person to place six wool tops, a continuous band of combed fibres in an untwisted form about an inch thick, in order of softness, by touch alone, five times. The whole surface of both hands is stimulated by subtle differences, muscular action being reduced to a minimum.

The samples were selected by practical men and the grading was confirmed by physical tests. The average grading of 15 persons with some trade experience, 15 untrained adults and 10 children show the same grading for fineness of fibre by sight and for softness by handle ; the correlation between sight and touch being perfect.

From this criterion individuals vary considerably. The results indicate that innate tactile ability in children and the combined results of natural ability and experience in adults may be registered. Sensory and manipulative ability should be capable of separation by degrees of differences and not included under general terms such as ' touch ' and ' handwork.'

Mr. L. I. Hunt.—*A study of fatigue and practice in a purely manual process* (2.45).

In many small groups of workers it is important for the management to know whether any workers are showing such signs of fatigue as to justify the introduction of rest pauses, with the consequent trouble of ensuring that they are properly used and not abused ; yet for economic reasons it is impossible to spend much time on such a study.

In a recent investigation this difficulty of keeping costs low was overcome by getting the workers to keep special records, which were used for calculations ; and, in spite of the apparent unreliability of the data, very good curves of performance were obtained. This result gives to the study considerable general interest to works managers, since it proves that a study of fatigue-effects in small groups can be made successfully at very small cost, provided that the whole-hearted co-operation of the workers has been obtained.

It was found that only one or two workers revealed symptoms of excessive fatigue, and that these could be cured without introducing rest pauses ; and further, that the loss through inexperience of any particular kind of work was negligible compared with the effects of the workers' views on monotony and boredom.

Mr. M. M. Lewis.—*The extension of meaning in children's earliest words* (3.30).

The tendency of children to extend the application of their words has been very frequently observed, the stock example being that given by Romanes of a child who, having learnt the word *quack* for a duck, applied it to the figure of an eagle on a coin and then to coins in general. This has commonly been regarded as a kind of primitive generalisation ; Stern, for instance, stresses the fact that the various situations to which a word is applied are, as a rule, objectively and affectively similar.

Emphasis on these features of the process leads to too narrow a view. As Dewey has pointed out, the functional similarity of the various situations also plays an important part. But there is yet another factor : the place of the word itself in the child's activity. He uses language as a means of dealing with his environment in a *declaratory* or a *manipulative* fashion.

From personal observation and the published records of children the author shows that these instrumental functions of language are of great importance in determining the extended application of the child's words. A complete account of this process must therefore consider the following factors : (i) the objective, affective and functional similarities of the various situations ; (ii) the declaratory and manipulative uses of language.

(Full Section Meeting.)

Dr. ROSA KATZ.—*Social contact of children speaking different languages* (4.15).

There exists a great number of factors influencing social contact between children speaking different languages. (1) The structure of the children's community (kindergarten, family, companionship in the streets). (2) Age. A young child does not realise the fact that his comrade speaks another language. (3) If there exists a rule regulating the community the children only need a minimum of words. (4) Social milieu. Children of the lower classes apparently do not realise that their comrades speak another language. (5) For children to understand one another it is important that their languages should be akin. (6) The understanding of the children is influenced by their knowledge or ignorance of the fact that they have different languages. (7) Some children make use of gesture language. There seems to exist a special ability for using gesture language.

Friday, September 7.

PRESIDENTIAL ADDRESS by Dr. SHEPHERD DAWSON on *Psychology and social problems* (10.0). (See p. 183.)

Prof. G. A. JAEDERHOLM.—*The development of conversation in early childhood* (11.0).

Dr. W. BROWN.—*Sleep and hypnosis* (12.0).

A comparison of the hypnotic state with that of natural sleep reveals deep-going differences as well as superficial resemblances. Tendon-reflexes diminish with the onset of sleep and eventually disappear, but are retained in all stages of hypnosis. Voluntary reactions to a given signal can occur in hypnosis, but not in sleep. But hypnosis can pass into sleep, and sleep into hypnosis, and mental dissociation with amnesia can occur in both conditions. Both states may be therapeutically recuperative, and both involve increased susceptibility to suggestion.

Mediumistic trance and cataleptic stupor show close similarities to the hypnotic state. Sleep is linked up with other manifestations of these states in the phenomenon of dreaming.

Measurement of the psycho-galvanic reactions in these various states throws further light on their psycho-physiological resemblances and differences.

AFTERNOON.

(Section meeting in two divisions.)

Division 1.

Miss G. B. DODDS.—*The learning of French in a Scottish school* (2.0).

Language, essentially speech, is acquired in a situation, i.e. an actual experience, and practised as a skill, in the situation to which it belongs. Thus the direct association is formed between the word and the idea. Simple plays in French, on gramophone records, provide the French situation, and, acted in class, afford the necessary practice in speech.

Illustrations from the classroom indicate that language thus acquired recurs spontaneously for self-expression when required in a similar situation.

Lessons and exercises are based on the phrases and sentences already memorised and acquired by ear and imitation.

Dr. W. BROWN.—*The theory of two factors versus the sampling theory of mental ability* (2.45).

According to the two-factor theory of Prof. C. Spearman, the abilities measured by suitably chosen mental tests are divisible into two factors each, one being common to all (the general factor, g), while the other is in each case specific and independent (the specific factor, s).

According to the sampling theory of Prof. Godfrey Thomson, any one mental ability is due to the operation of a certain set of factors, another ability to another set, and so on ; and these sets may overlap in any manner.

In a joint research with Dr. W. Stephenson 19 non-overlapping mental tests were applied to a homogeneous group of 300 boys, aged 10 to 10½ years, giving 171 correlation coefficients, of which one was later omitted for definite psychological reasons. Tetrad differences (of the form $r_{12}r_{34} - r_{13}r_{24}$), to the number of 22,712, were calculated from these 170 coefficients after they had been corrected by partialling out a ' verbal factor ' involved in some of the tests.

The observed frequency-distribution of tetrad differences was then compared with the theoretical distributions (Type II*a* Pearson curves) to be expected on the assumptions of the two theories, respectively, and was found to approximate very closely to the two-factor theory.

There were difficulties in determining the most probable or suitable standard-deviation for the sampling theory curve, but the observed values of $\bar{r}$ (0·413) and σ_r (0·087) were the fundamentally important facts to be taken into account here.

Dr. S. J. F. PHILPOTT.—*Conventional measures of fatigue and their meaning* (3.30).

Division 2.

Miss J. A. WALES.—*A description of the methods of vocational guidance used in Berlin* (2.0).

After a short introduction the paper gives a brief description of the educational system of Berlin and notes the chief points of difference from the London system. It outlines the arrangements whereby trade talks are given by the Ministry of Labour vocational advisers to children about to leave school, and explains the organisation of the juvenile departments of the Employment Exchanges where individual advice is given and cases of difficulty are referred to the special Medical Officer if the difficulty is one

of health, or to the psychological department if there is doubt as to vocational aptitude. The tests used in the psychological laboratory are very briefly touched on. Comparison is made with London methods of state vocational guidance, and finally a few points of interest which have emerged during the present Nazi régime are noted.

The National Institute of Industrial Psychology.—*Results of a vocational guidance experiment in Fife* (2.45).

An experiment, financed largely by the Carnegie Dunfermline Trust, was conducted for the National Institute by Dr. F. M. Earle, assisted by Mr. J. Kilgour and Miss J. Donald. Children, 472 in number, attending urban and rural schools in Fife were examined psychologically during session 1928–29, when the majority were of age 11 or 12. They were re-examined at approximately yearly intervals during the subsequent period of school attendance. The 378 pupils who had left school by the summer of 1932 were ' followed up ' in their occupations. The town children were on the whole superior to the country children in abstract tests but inferior in practical tests.

The correlations of the results of successive applications of the same tests vary considerably, the verbal intelligence tests having the highest consistency during the age period under review ; and the figures shed light on the question of the age at which vocational studies should begin.

The ' follow-up ' studies yield tentative estimates of the minimal qualifications necessary for various kinds of work. The results of the experiment would appear to have important bearings on educational practice as well as on vocational guidance.

Mr. C. A. Oakley.—*Some recent surveys in connection with vocational guidance* (3.30).

The ultimate aim in vocational guidance is that every child when leaving school should receive advice on the choice of his vocation by psychological and other methods. Increasing attention has been given in recent years to the establishment of careers masters and mistresses in schools to deal with what may be described as the ' normal ' cases.

Equipping these advisers with the necessary information for carrying out this work is therefore a matter of immediate importance, and early in 1933 two surveys were undertaken as part of a larger scheme. The first survey covered all the vocations secondary school children are likely to enter, beginning with accountancy and ending with wholesale selling. The chief governing or organising professional body was selected in the case of each vocation. Altogether there were between seventy and eighty of the bodies. The secretaries, education directors or other officers were visited, and as the result of many discussions an occupation survey has been prepared in which, among other matters dealt with, information about the necessary abilities and other qualities is set out in systematic form.

The second survey was made with the intention of finding out what psychological tests for children over eleven years old are at present being used in Great Britain.

Mr. A. Rodger.—*The results of a Borstal experiment in vocational guidance* (4.15).

Four hundred ' new ' Borstal boys were examined by the National Institute of Industrial Psychology at the Wormwood Scrubs Boys' Prison,

the collecting-centre for the various Borstal institutions. Recommendations were drawn up for each boy, but these were forwarded to the institutions only for alternate boys. The remainder formed a control group, and were allocated to their work-parties by their housemasters in the usual way. Of those who were put into parties judged suitable for them by the National Institute, 69·5 per cent. were successful. Of those who were put into parties judged suitable for them by their housemasters, 45·6 per cent. were successful. This difference is statistically significant. A survey of the National Institute's ' failures ' shows clearly the importance of the part which should be played in vocational guidance by the study of temperament.

Monday, September 10.

Dr. L. S. Penrose.—*The inheritance of mental ability* (10.0).

The intelligence of persons related in various degrees to mentally defective patients was ascertained. All the individuals concerned were tested by standard intelligence tests. For purposes of comparison a method of obtaining a mental ratio had to be evolved, which was valid for all ages, juvenile and adult.

The following results were obtained from the investigation :

(1) The mean intelligence of the relatives is higher than the mean intelligence of the defectives themselves and is reasonably close to the expected value inferred from the law of ancestral regression.

(2) There is no direct correlation between mentality of patient and mentality of relative.

It is concluded from (1) that multifactorial hereditary influence plays a large part in determining intelligence. On the other hand, it is concluded from (2) that there exist variations in intelligence, of considerable magnitude, which are due to non-genetic causes.

The problem of the relative importance of environment and heredity in determining mental ability can be further studied by comparing half sibs with the children of patients' full sibs.

Joint Discussion with Section L (Education, *q.v.*) on *Some aspects of psychological and child guidance clinics* (11.0).

Afternoon.

(Section meeting in two divisions.)

Division 1.

Dr. R. W. Pickford.—*The group psychology of the Barbizon painters* (2.0).

The Barbizon painters formed a group with a definite life-history in the middle of the nineteenth century. The exhibition of English naturalistic landscape paintings in Paris stimulated a latent reaction against the hardened classical tradition. This reaction, including the Barbizon movement, was an expression of the increasingly bourgeois public. Corot, the first of the Barbizon painters, was but mildly reactive, and retained classical affinities. Rousseau and Millet followed, reacting violently. Other members were non-classical from the start. After somewhat independent reactions, these painters formed a group. They were intimately interested in Barbizon and

the forest of Fontainebleau. They met with academic opposition, and their success depended on bourgeois political advances after 1830. Their tradition died because other developments of painting attracted good men, and because it became a sentimental convention. The relations of members were mainly of comradeship, and the principal members were strikingly independent. Corot, the leader, held the position by his comradely qualities, ability to express the spirit of the times, and outstanding genius. The group was an integral system, a framework necessary to the activities of its members, and maintained itself by expressing tendencies and fulfilling needs of the community.

Dr. G. G. NEILL WRIGHT.—*The psychological description and classification of forms of social maladjustment* (2.45).

A formal analysis of the possible types of social maladjustment may have practical value in relation to problems of (*a*) the socially maladjusted individual, and (*b*) large scale social and political maladjustments. Such an analysis is most readily carried out by examining maladjusted personal relations: for it is necessary, and in the case of the relations between two persons it is possible, to take into account the relevant mental states and structures of both minds and to allow full weight to both points of view.

Two persons may be said to be maladjusted to one another when their common mental frame is so organised as to hinder the normal expression and development of their personalities in relation to one another. Such hindrance may result from (*a*) a primary concord with opposition in respect of intensity, frequency or duration; (*b*) a primary concord with opposition of other tendencies, e.g. an appetitive concord with a co-operative opposition and *vice versa*; (*c*) a primary concord with oppositions arising out of differences of intelligence or relevant knowledge or experience.

Such obstructed interactions admit of various degrees of adjustment through 'trial and error' and other-conscious processes: but such adjustment may be hindered by (*a*) the development of anger as a result of instances of the original opposition, and (*b*) the development of ideational structures in which the nature of the opposition is misconceived.

Mr. J. DREVER, jun.—*Insight and opinion* (3.30).

Controversy has tended to influence the determination of criteria for insightful behaviour in such a way that extrinsic features have been unduly emphasised. Suddenness is a case in point. Experiments have been devised which seem to show that insight need not appear suddenly. The earlier stages have not been detected by the Gestalt experimental technique, but if they can be demonstrated, a study of them should throw some light on the psychological conditions of insight. Opinion and guesswork may cover these stages and are thus relevant to the psychology of learning.

Division 2.

Dr. R. B. CATTELL.—*The place of the practising psychologist in the educational system* (2.45).

The psychologist, as an integral part of the local education service, is a long overdue necessity in modern education. His functions, though numerous, cannot yet be delimited, but must be decided by the experience and experiment of the next few years.

His main value to the system is as a psycho-therapist, treating difficult, neurotic and delinquent children who are far more numerous and much more neglected than is commonly supposed. He is also needed to grade normal children, to select defective children and those with special educational disabilities. Thirdly, his services are required in designing schemes of vocational guidance. Fourthly, experience shows that the psychologist's evidence will be sought in a great variety of matters pertaining to curriculum and school organisation.

Among the unforeseen consequences of such a ramification of function is the necessity that arises for training a nucleus of teachers in routine mental testing.

The plan of organising the psychologist with an assistant and a trained social worker in a Psychological Clinic within the school system (after the pattern proposed by Professor Burt) compares very favourably with the American pattern of Child Guidance Clinic, both with regard to the effective treatment of large numbers of children and from the broader standpoint of furthering research. The university training of the psychologist, however, is not yet adapted adequately to the needs of the practising psychologist.

The education authorities that realise what extensive services the psychologist can offer in the improvement of educational technique are still in a minority.

Dr. O. A. Oeser.—*Some psychological aspects of laissez-faire in education: the cult of pure reason* (3.30).

Psychologically, the doctrine that children should be allowed free expression for all their impulses is preferable to the older methods of severe discipline, provided it is not carried to extremes. Unfortunately many logical and psychological fallacies, such as the confusion between repression and inhibition and the psychology of habit, underlie the practical applications of this doctrine in modern schools. Of these fallacies the most interesting are 'Retrospective Idealism' and the 'Transcendental Idealism of Pure Reason.' The former involves lack of training in responsibility, and lecturing instead of teaching the technique of acquiring knowledge. The latter leads to the attempt to force children *under all circumstances* to adopt a reasonable attitude. But the effort to formulate impulses in logical terms is often exhausting for the child, particularly during the negative phases of puberty. The teacher who adopts the purely reasonable attitude furthermore forces the child's aggressive impulses to recoil upon itself. Finally, this attitude implies a lack of insight into the psychology of types. That is, the teacher attempts to enforce disintegrate adult modes of response on integrate youth. What is needed is greater insight into the positive psychological value of leadership and the necessity of insisting on action once reasons have been given.

Tuesday, September 11.

Joint Discussion with Section D (Zoology, *q.v.*) on *The interpretation of animal behaviour* (10.0).

Afternoon.

Dr. B. P. Wiesner.—*Analysis of the maternal drives in the rat* (2.0).

Maternal behaviour in the rat cannot be reduced to a simple motivating factor since dissociation of the components is observed. The constituent

(partial) drives show independent variation with respect to structure, intensity and object. To regard 'drives'—even constituent drives (*Partial-Triebe*)—as determined units of motivation is fallacious.

Since structure, intensity and object of any 'drive' vary, they must be analysed separately. In the case of the retrieving drive, analysis shows that its *structure* can only be defined in very general terms, implying foresight and insight. The intensity of the drive varies widely and without clear correlation with structure; it can be measured because there appears to exist a functional relationship between intensity and the range of 'objects' towards which the drive is directed. Mother rats, impelled by a strong retrieving drive, will carry to the nest, kittens, chicks, ducklings, young rabbits, etc., but they may refuse rats smaller but older than the rabbits they accept. The decisive property of the 'object' seems to be its age.

The maternal drives awaken, as a rule, towards the end of pregnancy or after parturition. An analysis of the physiological mechanisms involved shows that the ovaries are not directly, if at all, involved. But the anterior lobe of the pituitary appears to be engaged in the induction of maternal behaviour; many virgin rats exhibit maternal behaviour after having been treated with anterior lobe extracts.

Prof. D. Katz.—*Some problems of the psychology of needs* (3.0).

The study of needs seems to be one of the most important tasks of modern psychology. One should first try to obtain a general view of the whole range of needs (vital, social, artistic, religious, etc.). When we have got this, two other tasks remain to be undertaken. The objects which serve the satisfaction of needs must be pointed out and the methods by which needs are satisfied must be investigated. The different needs all reveal the same fundamental laws. No other need offers, from the point of view of content and method, such a profitable object of investigation as the satisfaction of hunger. In dealing with the satisfaction of hunger we can show some of the fundamental laws of needs. The laws of satisfaction of hunger reveal the dynamic relations of all needs, how they are influenced by inner and outer factors, and by historical factors which to some extent are rational and to some other extent irrational. The concept of need may in some fields be more helpful than the concept of instinct, particularly in such cases where we meet an amazing plasticity in the adaptation of the behaviour to unusual conditions.

SECTION K.—BOTANY.

Thursday, September 6.

Presidential Address by Prof. A. W. Borthwick, O.B.E., on *Some aspects of forest biology* (10.0). (See p. 195.)

Mr. J. Ramsbottom, O.B.E.—*Fungi and forestry* (11.0).

Mr. J. Bryan.—*The preservation and preparation of timbers for industrial purposes* (12.0).

The importance of a thorough knowledge of the behaviour of wood in order to utilise it to the best advantage is stressed.

The seasoning of wood is described and the various methods of seasoning and the moisture content requirements for different purposes.

Under certain conditions wood is subject to decay—probably one of its major defects when used for industrial purposes. Methods of preservation are described. In certain cases these may consist of details of construction. The most important methods are, however, treatment with toxic chemicals. The different types of chemicals and the methods of applying are described for the different industrial purposes for which wood is used.

Afternoon.

Prof. W. Seifriz.—*The structure of protoplasm* (2.15).

Mr. T. A. Oxley.—*The influence of light and temperature on growth* (3.0).

Lemna minor has been grown under carefully controlled conditions of light and temperature, the temperatures ranging from 10° to 35° C. and the light intensities from 80 foot-candles to 1,600 foot-candles. Growth rate, dry weight per frond, and area per frond have been measured under each of the forty-eight sets of conditions. From the results obtained the interaction of light and temperature on plant growth has been analysed and conclusions drawn which may be applicable to green plants generally. Notably, evidence has been obtained to show that light does not control growth solely, or even chiefly, by limiting the amount of assimilate formed, but that there is some photochemical reaction other than assimilation which controls growth.

Dr. R. E. Chapman.—*The absorption of water vapour by the aerial parts of Egyptian desert plants* (3.30).

The experiments described in this paper indicate that some plants of the Egyptian desert can, in an atmosphere of high humidity, increase in weight (presumably by the absorption of water vapour by their aerial organs). In the Egyptian desert, owing to the great difference between day and night temperatures, it is often found that during the night the air humidity approaches saturation even in summer, and hence may be the source of an appreciable part of the plant's water supply in plants like *Reaumuria histella*, which have salt crystals on their leaves. These crystals apparently form part of the mechanism of absorption of water vapour, as without them the plants do not increase in weight in atmospheres of high humidity.

In this way about one-sixth of the plant's loss by transpiration may be replaced by absorption of water vapour at night.

Mr. W. A. Clark.—*The effects of carbon monoxide on tomato plants and potato tubers* (4.0).

Tomato plants subjected to a 2 per cent. concentration of carbon monoxide gas in a moist chamber produce stem-borne roots. The anatomy of such roots is dealt with.

Halved potato tubers were treated in a similar manner to the tomato plants. The gas first caused proliferation of the lenticels, but later, proliferation takes place freely from the tissues underlying the periderm. Abnormal development of the shoots also occurs, the bases of the shoots becoming swollen and covered with proliferating lenticels. The gas also hinders cork meristem formation at the cut surface.

No roots were induced from mature tubers, but in the case of entire potato plants subjected to the gas, roots appear to arise from the daughter

tubers in association with the buds. Proliferation takes place in the parent tuber from the cells beneath the periderm (which in places is ruptured) and the lenticels of the daughter tubers also proliferate.

Friday, September 7.

Dr. Kathleen Blackburn and Mr. J. Wilkinson.—*A preliminary report on a cytological method of distinguishing Salix alba* var. *cœrulea from closely related species, varieties and hybrids* (10.0).

Since great difficulty has been found on ordinary morphological grounds in distinguishing the true cricket-bat willow (*Salix alba* var. *cœrulea*) from spurious forms, chiefly hybrids between *Salix alba* and *S. fragilis*, the possibility of using the chromosome characters is being explored. The root tip cells of *Salix alba*, *S. fragilis*, and crosses between these species, all show seventy-six chromosomes. These are all very small, but certain characteristic pairs found in *S. alba*, including the bat willows, are absent in *S. fragilis*. In undoubted hybrids the characteristic chromosomes occur singly. Other small differences help in distinguishing *S. alba* from *S. fragilis*. Typical *S. alba* differs from *S. alba* var. *cœrulea* in having four instead of two chromosomes with satellites ; this is an uncertain character, since it is always possible for a satellite to be present but not visible. Since the major difficulty in the field seems to lie in distinguishing the *alba-fragilis* hybrids from the true bat willow, it is fortunate that it is just here that the chromosome studies afford most help.

Dr. J. K. Spearing.—*Cell structure of the Blue-Green Algæ* (10.20).

The present investigation of the structure of the Cyanophycean cell emphasises the homology of the so-called ' central body ' with the nucleus of higher plants. This conclusion is based upon its structure, its behaviour during cell-division, and upon micro-chemical work. In *Oscillatoria tenuis* proper chromosomes are formed and apparently divide normally, although the appearances produced are unusual. In other related species nuclear division is essentially similar. In no case has a nuclear membrane been observed ; but in *Stigonema mamillosum* one or more nucleolus-like bodies are found in each cell of the older parts of the thallus. In some species the nucleus never reaches a resting stage during periods of active growth—the chromosomes persisting throughout the interphase. In other cases a well-marked reticulum characterises this stage. The small size of the nuclei, the absence of a nuclear membrane and the presence of other substances which stain like chromatin have been responsible for much of the confusion concerning the cytology of these plants.

Dr. J. Caldwell.—*Some aspects of virus diseases in plants* (10.40).

A large number of experiments have been carried out with what have been shown to be two strains of the same virus, viz. the ' green ' and ' yellow ' strains of the virus of yellow mosaic of tomato (Johnson's Tobacco virus No. 6). It has been found that the ' green ' strain has a protective action on plants and induces immunity against the ' yellow ' strain in the tomato plant. This and other observations have led to the conclusion that the differences in symptom picture presented by virus diseased plants under different environmental conditions may to some extent be due to the existence of strains in the virus causing the disease.

The effect of one virus on another in plants has been investigated in some

detail, and evidence has been obtained which shows that three possible interactions may take place—the presence of the first virus may (*a*) affect (often making more severe) the symptoms induced by the second virus, (*b*) prevent the appearance of symptoms characteristic of the second virus, which nevertheless multiplies in the tissues, or (*c*) prevent the multiplication of the second virus in the tissues.

Dr. Mary J. F. Gregor.—*A disease of Bracken and other ferns caused by Corticium anceps* (11.5).

Corticium anceps is a vigorous parasite of Bracken in moist, shady situations. It has once been found attacking Male Fern, and infection experiments indicate that the Prickly Shield Fern is also to some extent susceptible. The disease occurs almost exclusively upon the frond of the Bracken and has never been seen to extend more than a few inches down the petiole ; it does not attack the rhizome. The fungus creeps over the lower surface of the pinnæ and rachis and at first remains entirely superficial. Soon, however, penetration of the host is effected, mainly by means of infection cushions, though individual hyphæ often enter through the stomata. The external mycelium continues to spread and ultimately forms a whitish felt-like covering over the lower surface of the frond. The infected tissues become brown and brittle, and in severe cases the pinnæ break off, leaving only the bare discoloured rachis. In the later stages of the disease sclerotia and basidia are developed upon the superficial mycelium. The parasite grows readily in culture and forms typical sclerotia, but no basidia. The basidiospores germinate in culture by means of a germ tube, but when germinating *in situ* on the hymenium they sometimes form secondary spores.

Dr. Edith P. Smith.—*The ecology of the island of South Rona* (11.35).

South Rona lies between Skye and the mainland ; it is about 4½ by 1¼ miles, and reaches a height of 404 ft. There are steep cliffs on the east side and two large inlets (Big Harbour and Dry Harbour) on the west side. The island consists of worn Lewisian gneiss, in a series of rocky ridges and valleys running north-west to south-east. There are few streams, and only two small bodies of water : one of these was newly recorded. The vegetation is sparse, of moorland type mainly, merging into cotton-grass bog on upland valleys, and marsh (salt and fresh) on west coast. East cliffs are topped with bracken-invaded pasture. No natural woodland except scrub birch and willow, but remains of *Pinus sylvestris* wood in a peat bog, and a submerged forest (mainly alder and birch) were located at Dry Harbour. Once supported a population of 159 ; present population, 3. The abandoned arable had become a pure society of *Juncus communis.* A ' sea-weed farm ' (to supply manure for fields) was located at one of the deserted villages. Slight differences in the content of the moor flora on tertiary intrusions were noted.

Dr. Olive D. Dickinson.—*The distribution of certain constituents of the flora of Bas-Languedoc* (12.5).

A study has been made of 140 species in Bas-Languedoc showing disjointed distribution, which appears impossible of explanation by dissemination under existing conditions. The majority are distributed throughout the Mediterranean basin, including the islands of the Mediterranean Sea ; and all are species of clearly defined—often very isolated—systematic position indicating their ancient character.

The species occur in colonies having certain features in common, i.e. :

(1) They occur chiefly in the southern part of Bas-Languedoc, in warm, sheltered valleys, and on southern slopes.

(2) They occur in the early stages of plant succession, and not where the climatic climax has developed.

(3) They are in places difficult of access to man and thus protected from destructive effects of cultivation.

(4) They are, with rare exceptions, on pre-quaternary substrata.

We know from fossil records that the pliocene flora of the neighbourhood was similar to that of the present day, but richer in thermophile species. The characteristics of the colonies, and other features of distribution of our species, suggest survival. The colonies would appear to represent remnants of a more thermophile tertiary flora which, in a few favoured places, has been able to survive vicissitudes of climate during the quaternary epoch.

AFTERNOON.

Visit to Macaulay Research Institute.

Saturday, September 8.

Excursion to Dinnet Moor.

Sunday, September 9.

Excursion to St. Cyrus.

Monday, September 10.

JOINT DISCUSSION with Section D (Zoology, *q.v.*) on *Biological problems of fresh water* (10.0).

AFTERNOON.

Prof. J. H. PRIESTLEY.—*Vessel differentiation in Angiosperms* (2.30).

The ' strip method ' of studying cambial activity makes it possible to follow the course of one individual vessel for a comparatively long distance in microscopic preparations. A study of vessel differentiation by this method directs attention to the rapidity of expansion of the vessel segments and of the perforation of the more or less transverse cross walls. These processes take place when the wall of the future vessel is very thin. Vessel segments have been separated by maceration in this stage, as extremely thin-walled elements without signs of pitting.

By plasmolysis under suitable conditions it has been possible to show the presence of protoplasts in the segments of the vessels, after expansion and after the cross walls are perforated. In many vessels sheets of pectin are present, across the region of perforation, after the cellulose cross walls have perforated.

The study of vessel differentiation and vessel structure continues to emphasise the distinction between ring porous and diffuse porous hardwood types.

Dr. G. Bond.—*The influence of illumination on the development of the Casparian strip* (3.0).

Observations made by Priestley and his collaborators on a small number of plants suggest that the deposition of Casparian strips in the shoot of these plants is influenced by illumination. This matter has been further investigated in members of the Leguminosæ. The above authors' statements have been confirmed and extended to a number of related types, all of the sub-division *Vicieæ*. In the normal shoot of these plants a primary endodermis is present in the basal internodes only, while in the etiolated shoot the endodermal cylinder extends up to shortly behind the apex, and probably develops continually behind the latter. It is suggested that in these plants, although the shoot is potentially endodermis-forming, the secretion of the Casparian strip by the endodermal protoplast is suppressed by illumination. The reason for the development of the basal endodermis under normal conditions is as yet uncertain.

A less marked response to etiolation was obtained with the other types investigated, although certain species displayed a definite approach to the *Vicieæ* group.

Dr. S. Williams.—*Regeneration in the Lycopodiales* (3.30).

Regeneration of various organs has been observed in all the genera of the Lycopodiales. The author has experimentally induced regeneration in *Selaginella grandis*, *Lycopodium Selago* and *Isoetes lacustris*. Such phenomena will be described from the point of view of their bearing on various morphological problems and their relation to the intrinsic problems of regeneration only briefly mentioned. In *Selaginella grandis* regeneration of the shoot can be induced by removing the stem apices ; in these circumstances rhizophore rudiments become transformed into leafy shoots. In other species regeneration of roots from decapitated rhizophores has been recorded. Such results have a bearing on the interpretation of the rhizophore. In *Lycopodium Selago* various types of regenerative growths have been induced on the stems and leaves of young plants grown from bulbils. The facts relating to these have a bearing on various problems such as the nature of the normal bulbils, the significance of the protocorm and the factors underlying vascular tissue formation. Similar adventitious growths have been recorded by Holloway and Goebel for other species of Lycopodium. Osborn has described regenerative growths from isolated leaves of Phylloglossum which show features of interest for comparison with those described for *Lycopodium* spp.

Prof. R. J. D. Graham.—*The work of L. B. Stewart* (4.0).

It was Laurence Baxter Stewart's brilliant work on vegetative propagation by means of cuttings which attracted most attention. His success was achieved through careful observation and ingenious experiment.

Results attained may be summarised as relating to :

(1) *Selection of Cutting.*—Determined by character of plant (1912), position of severing cut (1912) and season (1927).

(2) *Preparation and Insertion of Cutting.*—Blanching (1923), treatment for resin and latex (1912), retention of leaves (1912).

(3) *Creation of Environment.*—Control of rooting medium (1912), aeration (1912), acidity (1922), water supply (1912), temperature (1912), disease.

(4) *Special Features.*—Response of cutting (1912), paring of callus (1912), cuttings without buds (stem internode, leaf, root), plants with horizontal branching (1927), inverted stem cutting (1927).

Tuesday, September 11.

JOINT DISCUSSION with Section M (Agriculture, *q.v.*) on *Soil and ecological studies in relation to forestry and grazing* (10.0).

Alternative programme for Members not attending the above discussion:—

Prof. J. DOYLE.—*Pollination in the conifers, particularly in the Abietineæ* (10.0).

In conifers the pollination-drop mechanism is much the commonest, occurring in the Cupressineæ, Callitrineæ, Sequoiineæ, Taxineæ, and probably most of the Podocarpineæ except *Saxegothea*, in which the pollen germinates on the scale. Germination of the pollen on the scale is also now well known as characteristic of the Araucarineæ. The Abietinean mechanisms are, however, much more varied. Some of these have been briefly referred to previously, but have since been more fully examined and other genera dealt with. In *Tsuga* the pollen falls on the scales, the long tubes growing like fungal hyphæ to the ovules in a manner similar to that of the Araucarineæ. In *Cedrus* the pollen, caught by a micropilar flap in the autumn, is held there till spring, when the nucellus, rather stigmatic at the apex, grows up to make contact with the pollen *in situ*. The mechanism in *Pinus*, paralleled apparently in *Picea* and to some extent in *Abies*, is associated with an exudation of fluid. The micropyle in *Pinus* is extended into two long narrow arms, to which pollen readily adheres. At night fluid is secreted, filling the micropilar tube, but in most species this fluid is to be found rarely, if at all, in the day period, being reabsorbed in the early morning hours. On reaching the level of the arms the fluid is drawn out as a film by surface tension up to about half their length. The pollen grains, being easily wetted, are quickly drawn into the fluid. Immediately after the pollen has been so drawn in, the fluid is reabsorbed by the ovule, the pollen being lodged on the nucellus, and the whole micropyle becoming dry internally within five or, at most, ten minutes. The wings on the pollen facilitate its neat lodging on the nucellus. Dichogamy seems characteristic of certain species. *Picea orientalis* appears to be interestingly intermediate between the normal *Pinus-Picea* type and the *Larix-Pseudotsuga* type with the large stigmatic swelling of the micropyle edge.

There are thus in the Abietineæ at least four main types of pollination mechanism, with additional variations in these.

Prof. T. M. HARRIS.—*The reproductive organs of the fossil Ginkgoales* (10.40).

The only reproductive organs which have been referred to the fossil Ginkgoales are a few resembling those of *Ginkgo biloba*, and none of these have been investigated in detail. Comparison of the cuticles of all the isolated fructifications and leaves in the lower Jurassic flora of Greenland has, however, provided reasons for referring to the Ginkgoales certain reproductive organs which differ greatly from those of *G. biloba*; among the male organs *Bernettia*, hitherto regarded as the female cone of a Cycad, and *Leptostrobus*, hitherto regarded as the female cone of a conifer; among female organs *Staphidiophora*, a new genus with the appearance of a bunch of currants. The bearing of these fossils on Gymnosperm morphology is discussed.

Dr. Margaret Benson.—*Hallé's new technique for the study of incrusted plant remains on primary rocks* (11.20).

Details are given on pp. 4 and 5 of Hallé's treatise, *On the Structure of certain Fossil Spore-bearing Organs believed to belong to Pteridosperms*, Stockholm (1933). Many of his microtome sections were sent to the Geological Survey Museum, London, and with his approval were entrusted to the author for further study.

Calathiops (Gœppert) has recently been demonstrated to be ovular and not synangial by three distinct lines of research :

C. Telovulum (*Telangium*, Kidston), because it gives rise ontogenetically to a *Calymmatotheca* and contains embryo-sacs.

C. Pterispermo strobus, by ocular demonstration. New specimen, *P. Bernhardti*, Gothan.

C. Schuetzia
C. Whittleseya } because they produce female spores.

Hallé's slides allow of the high power of the microscope. They reveal that the general structure of all the bodies he deals with is similar. What have been regarded as ♂-spores are either epidermal cells freed from their superincumbent cuticle and from non-cuticularised cells, or some few are embryo-sacs. The true ♀-spores, triradiate and minute, are sheathed in the epidermis of the cupules and nucellus of the young ovules.

These results throw light on *Eospermatopteris* and many other types.

Completely cuticularised, triradiate ♀-spores of the same size as their contemporary pollen grains, now demonstrated in Lower Carboniferous ovules, are new to science, and confirm Boyd Thomson's view that a seed is not a megasporangium.

Dr. T. Johnson.—*The leaf beds of Ardtun, Canna and Skye* (11.50).

Forbes in 1851, Starkie Gardner in 1887, Seward and Holttum in 1924 called attention, by description and illustration, to the interesting Eocene flora at Ardtun in the Isle of Mull. In the present paper an account is given of certain, mostly unnamed, collections from Ardtun, as well as from Canna and Skye, preserved in various institutions, viz. : The Glasgow City Museum (and Art Galleries) ; the Royal Scottish Museum, Edinburgh ; the Hunterian Museum (University of Glasgow); the Geological Division, University of Edinburgh ; as well as Mr. J. A. Inglis's specimens from a new locality in Skye. Half the collection made by Gardner in 1887, by the aid of a Government grant, was sent to Inveraray and is still, spite of all the author's efforts, not available for examination. The examination of this Hebridean flora supports the view of the origin of the flora from an earlier circumpolar flora which radiated southwards. The volcanic activities which gave us Staffa with Fingal's Cave, and the Giant's Causeway, followed by the Ice Age, destroyed many types, like *Onoclea* and *Libocedrus*, still thriving in N. America (Atlantic side more especially) and E Asia, or like *Sequoia* (Pacific N. America) and *Ginkgo* (E. Asia) in one region only. Certain forms, such as *Cupressus*, *Platanus* and *Quercus*, had already migrated further southwards and are now to be found in S.E. Europe or the Near East. Others like *Podocarpus* and *Araucaria* had gone still further afield. A detailed exploration of the fossil sites in Canna and Skye would be amply repaid. The flora, so far revealed, strengthens the view of the former existence of a land-bridge between Greenland and Britain.

AFTERNOON.

Demonstration of exhibits in the Botany Laboratory (2.30).

SEMI-POPULAR LECTURE by Prof. V. H. BLACKMAN, F.R.S., on *Botanical work on the cold storage of fruits and vegetables* (5.0).

DEPARTMENT OF FORESTRY (K*).

Thursday, September 6.

JOINT PROGRAMME with Section K (Botany, *q.v.*).

AFTERNOON.

Excursion to Fetteresso by permission of Major Duff.

Friday, September 7.

Mr. HENRY P. HUTCHINSON.—*General willow cultivation* (10.0).

Willows, for economic reasons, may be conveniently classified in two groups—viz. the group comprising species which are suitable for basket-making purposes, and the group comprising species capable of producing timber. Certain species serve both purposes, but generally the former attain the size of shrubs or bushes, while the latter become timber trees of considerable magnitude.

The cultivation of basket willows involves considerations of soil conditions, such as its state of natural fertility, and particularly its water supply. The degree of suitability of varieties to certain types of soil is important, and in the management of an established crop the recognition and appreciation of ecological factors are important economic determinants in the financial results attending the cultivation of the crop.

The research work on pests—insect and fungal—which has been carried out at Long Ashton has given valuable results in enabling control to be effected.

The factors affecting quality in the production of willow timber have been extensively investigated on the lines of propagation from seed and by vegetative methods.

Dr. J. BURTT DAVY.—*Occurrence of male trees of Salix alba*, var. *caerulea* (11.0).

The opinion is widespread that there is no male of *Salix alba* var. *caerulea* Smith. Buyers of first-class bat-timber reject (or give a lower price for) trees known to be males, and growers do not knowingly plant male ‘ setts.’ In East Anglia the writer has found staminate trees which clearly belong to this variety, having similar characters of inflorescence, leaf, bark and branching. Smith did not himself say that the staminate sex was unknown, and in 1829 a male specimen was figured in *Salictum Woburnense,* a book produced by the authority of the Duke of Bedford, who was in close touch with Smith, by whom, probably, the plates were seen.

No evidence has been produced, as far as we are aware, to indicate that

good or bad quality of timber is associated with sex; it is certain that bat-willow timber of poor quality is obtained from both female and male trees, but we lack evidence as to the quality of timber produced by well-grown male trees. This is an important point, for several of the phenomenally vigorous seedlings being grown from seed obtained by the author in 1932 prove to be males.

Dr. R. MACLAGAN GORRIE.—*Forest Research Institute at Dehra Dun, India* (11.25).

A forest school was founded in 1878, but it was not until 1906 that research workers were appointed to deal with Indian silvicultural and forest utilisation problems. Over 100,000 square miles of forest in India and 150,000 in Burma are under the Forest Department, apart from large areas under Indian States and private ownership, and the annual revenue has been as much as £3,000,000 in India and £2,000,000 in Burma. It is now obvious that any further increase must depend upon extensive research. A fine new institute was built and opened by Lord Irwin in 1929. In the grounds are several hundred acres of demonstration forest, arboretum, fruticetum, nurseries, and a minor forest products garden. The main building houses the offices and laboratories of silviculture, botany, entomology, and forest economy, and each of these branches has a large museum hall arranged to show the activities they are engaged in. These are increasingly visited by the public and by organised parties of students, soldiers and excursionists. Under separate roofs are the chemical laboratory, insectary, sawmill, pulp and paper plant, and wood workshops, and there is good accommodation for the whole staff of some 30 gazetted officers and 300 assistants, artisans, clerks and subordinates. Some of the problems dealt with by each branch were described and illustrated by 16-mm. films.

AFTERNOON.

Excursion in city and neighbourhood in connection with amenity tree planting.

Saturday, September 8.

Excursion to Ballogie by permission of Col. J. R. Nicol, O.B.E.

Sunday, September 9.

Excursion to Durris Estates.

Monday, September 10.

TREE-PLANTING IN TOWNS AND THEIR NEIGHBOURHOOD, WITH SPECIAL REFERENCE TO GENERAL AMENITY PLANTING (*Section K room*, 10.0):—

Lord Provost HENRY ALEXANDER.—*Town planning with reference to general amenity planning.*

The preservation of trees and woodlands as promoting general amenity is an important feature of town and country planning and is now recognised

in legislation. An account is given of the Aberdeen and District Joint Town Planning Scheme, 1933, which covers an area of some 96 square miles and under which arrangements have been made for the protection of landscape features along river valleys and upon hills and other commanding points. The Local Authority is empowered to establish a register of trees upon which it may place trees or groups of trees which, in its opinion, should be preserved. In various agreements, which have been effected with proprietors, it is provided that the owner, while at liberty to fell ripe timber in the course of good forestry, shall not do so in a manner to impair the wooded amenity and aspect of the area. This scheme was carried through under the Act of 1925, but the Act of 1932 takes the principle of re-planting a stage farther and empowers a local authority to put areas of woodland on the register and to insist upon re-planting in accordance with good forestry, subject to appeal to the Forestry Commissioners.

Sir John Stirling Maxwell, Bt.—*Tree-planting in towns and neighbourhood.*

Major S. Strang Steel.—*Roadside planting.*

Attention is drawn to the importance of public parks for rest, recreation and education. The species of tree and shrub most suitable for planting are discussed. The points in connection with planting trees on roads and near farms for general amenity purposes are considered. How planting may be done most economically and with the greatest possibility of success is discussed fully. The scheme drawn up by the Royal Scottish Forestry Society for helping and advising in amenity planting is outlined.

Mr. W. Dallimore.—*Amenity planting and the preservation of natural woodlands.*

Attention is directed to the necessity for preserving trees if the fair appearance of the countryside is to be maintained. Amenity trees are discussed as definitely apart from trees grown for commercial purposes, and after a general discussion of the question special attention is paid to garden and park trees, field and hedgerow trees, shelter and amenity plantations, woodlands open to the public, roadside trees, trees on commons and moorlands, trees in national parks, and those in natural woodlands.

Mr. W. B. Clark.—*Town trees and shrubs.*

(1) Features which influence the beautifying of cities, and the importance of trees towards this end.

(2) A new appreciation of trees, etc., by property owners, those possessing gardens, etc., and the transformation of ordinary and drab surroundings.

(3) The important relationship of trees to public parks, particularly in the raising of moral and educational standards of the community.

(4) The rapid advance of Town Planning Schemes towards the ideal city.

(5) Difficulties which have to be contended with in the process of tree-planting.

(6) Typical examples of avoidable tree destruction and the devastation thus caused.

(7) Effect of artificial light on tree development.

(8) Utility of trees in relation to bird life.

(9) Selecting trees for planting.
(10) The vital importance of tree-pruning.

Discussion.

Col. J. D. Sutherland, C.B.E.—*Summation.*

Afternoon.

Mr. J. C. Grassie.—*Demonstration of timber testing and laboratory practice for forest engineering students* (2.15). (*In the Engineering Department of the University, Marischal College.*)

Tuesday, September 11.

Joint Discussion with Section M (Agriculture, *q.v.*) on *The application of soil and ecological studies to the problems of land utilisation for forestry and grazing* (10.0).

Demonstration.

(Continuously for the period of the meeting) :—

The preservation of timber, by the British Wood Preserving Association in laboratories adjacent to the meeting room.

SECTION L.—EDUCATIONAL SCIENCE.

Thursday, September 6.

Presidential Address by Mr. H. T. Tizard, C.B., F.R.S., on *Science at the Universities : Problems of the present and future* (10.0). (See p. 207.)

Research in Education :—

Dr. N. T. Walker.—*Recent developments in educational research* (11.0).

The paper surveys, within the limits of time assigned, some of the results of recent scientific research in education. Special attention is given to the work of the Scottish Council for Research in Education, and, in particular, the results of the Council's survey of the intelligence of Scottish children are discussed. In connection with research on the problem of the reliability of examinations, reference is made to a recent Aberdeen experiment. Mention is made of investigations into one of the fundamental problems in educational theory, namely, the relative importance of nature and nurture in individual development. These inquiries include the novel experiment conducted by Prof. and Mrs. Kellogg, which consisted in 'adopting' a female chimpanzee of seven and a half months and bringing her up along with their infant son for a period of nine months.

Mr. F. W. REECE.—*Intelligence testing of secondary school boys at the Liverpool Institute* (11.30).

Since 1924 a series of intelligence tests has been applied to the whole school, and a record of each boy's score kept. Altogether the school has been tested seven times, and the last four occasions have been at intervals of two years. Use has been made of the results for promotions, and for grading purposes within a block of forms, but they have never been the sole and seldom even the deciding factor. The main object in view when the tests were put together was to obtain good results in the age groups 11–14, so that, using the results in conjunction with the ordinary examinations, promoted boys, and especially new boys, in these groups might be as correctly placed and graded as possible.

In addition to this original purpose, the scores have since been used for a variety of purposes. For instance, as a basis of comparison between fee-payers and scholarship boys. In this case they indicate in general a marked superiority of scholars over fee-payers throughout their school careers. Roughly the norms of the fee-payers are equal to the norms of scholars who are three years younger. On the results of these tests it may fairly be concluded that the number of scholars admitted might be greatly increased without there being any likelihood that the general level of intelligence of the scholars would not still be higher than that of the fee-payers.

A record has also been kept of the post-school successes of those boys who have proceeded to universities, and a comparison made between the academic honours gained by them and their intelligence quotients when at school. The number of boys considered is not large enough to lead to any definite conclusions, but some points of general interest are noted.

Mr. D. N. HOWARD.—*The relative merits of the laboratory* (*practical*) *and demonstrative methods of teaching science* (12.0).

This investigation constituted an inquiry into the relative values of the 'laboratory' (practical) and 'demonstration' methods of teaching science. In the 'demonstration' method the teacher performed all experimental work, in the 'laboratory' method the pupils did so.

For comparison three pairs of parallel groups were employed, each two groups of a pair being approximately equal in mental, scholastic and scientific ability. After preliminary tests one group of each pair was taught exclusively by one method for eight months. Final tests enabled differences between mean scores to be obtained representing the measures of relative progress. Mathematical treatment was adopted to measure the reliability of the tests and the probable errors of the differences of means upon which the findings were based.

Summary of findings :

(1) In the development of those characteristics termed generally 'scientific ability' neither method establishes definite superiority with pupils of all types.

(2) For pupils who are mentally bright and who have had previous systematic training the 'demonstration' method produces the better results.

(3) The 'laboratory' method is consistently better for dull or untrained pupils.

Discussion. (Mr. J. L. HOLLAND; Miss M. YOUNG; Prof. J. J. FINDLAY; Miss G. B. DODDS.)

Friday, September 7.

THE DEVELOPMENT OF POST-PRIMARY EDUCATION DURING THE PRESENT CENTURY :—

Mr. F. R. G. DUCKWORTH, M.B.E.—*The actual development in England from the passing of the Act of 1902* (10.0).

Since it is impossible in the short time at the lecturer's disposal to give a full account of the development of all types of post-primary schools in the last thirty years, attention is, in the main, concentrated upon secondary schools, but not without reference, at appropriate places, to central schools, senior elementary schools, junior technical schools and trade schools. Particular points are : the selection of pupils ; the growth in numbers of pupils ; progress in the design of school buildings and in equipment ; the staffing of the schools ; curriculum, organisation and examinations ; state and municipal control.

It is suggested that on the whole the trend of development has been from control to freedom and from an attempt to impose the school on the child to an attempt to fit the school to the child—a process hindered on the one side by difficulties in finance and administration, and on the other by philosophic doubts peculiar to our age.

Mr. W. W. MCKECHNIE.—*The actual development in Scotland from the passing of the Act of 1902* (10.30).

(*a*) *Local Authorities.*

Act 1872. The parish was the administrative area, and the local authority was the School Board.

Act 1918. 947 School Boards make way for 38 *ad hoc* Education Authorities, one for each county, and one for each of the five large burghs.

Act 1929. Abolishes the *ad hoc* Authority and transfers administration to 35 bodies—31 County Councils and the Town Councils of large burghs.

(*b*) *The Compulsory Period.*

1901. Compulsory period of education extended to 14 (therefore 1903 Supplementary Courses).

1918. Age to be raised to 15 for all pupils, and compulsory Continuation Class instruction to be provided up to 18, on an appointed day. These provisions not yet operative.

(*c*) *The Range of Education.*

1898. The administration of Science and Art grants transferred from the Directory of the Science and Art Department to the Scottish Education Department.

(*d*) 1902. Royal Commission on Physical Education. Development of physical education.

Act 1908. Medical inspection a duty. School Boards have also duty to see that scholars are fed and clothed.

Act 1913. Provided for medical treatment.

(*e*) *Code* 1902. Provision for education of physically and mentally defective children.

Act 1906. Education of Defective Children (Scotland) Act.

Act 1908. Increases powers for dealing with defectives.
Act 1913. Mental Deficiency and Lunacy (Scotland) Act converts powers into duties.
Code 1923. Provision for backward children.

(*f*) 1903. Employment of Children Act.
1904. Prevention of Cruelty to Children Act.
1908. Children Act.
1908. Power to maintain agencies for employment.
1918. Extension of these powers.
1932. Children and Young Persons Act.

(*g*) *The* 1918 *Act.*
(1) Transferred the voluntary schools to the local authorities, with safeguards. (2) Charged each local authority with the provision of primary and secondary education. (3) Introduced power of facilitating attendance at Secondary Schools, Universities and Central Institutions by means of bursaries and maintenance allowances. (4) Minimum National Scales of Salaries. (5) Library provision. (6) Nursery Schools.

(*h*) Secondary education. Size of classes. School buildings.

Dr. Cyril Norwood.—*The developments which might have been expected to meet the requirements of the majority of present-day pupils* (11.0).

Sir Josiah Stamp, G.B.E.—*The developments required from the world and economic point of view* (11.30).

Discussion. (Mr. H. T. Tizard, C.B., F.R.S.; Dr. W. W. Vaughan, M.V.O.; Sir Richard Gregory, Bt., F.R.S.)

Afternoon.

Visit to Hilton School.

Monday, September 10.

Medical Aspects of Education :—

Col. C. J. Bond, C.M.G.—*The physiological and psychological development of the child and the adolescent, and the claims thereby made on education* (10.0).

Introduction.—Education in regard to the environment.
The environment of civilised mankind to-day may be divided into—

(1) The world of matter and natural forces.
(2) The world of life, more especially human life in its individual and collective aspects.

We may call (1) the *External* and (2) the *Internal* or human environment.
Education and Training for Life.—There are three important spheres of life in which education, regarded as a training for life, has so far failed to

equip the young citizen. These are : (1) sex, marriage, and parenthood ; (2) citizenship ; and (3) vocation or occupation. These are considered in detail.

The place of biological instruction in the school curriculum.

The relation of biology to chemistry and physics.

Biology from the cultural point of view and as a mental discipline.

Education and the right use of leisure.

Education, knowledge and conduct.

Modern education requires developing and extending on biological lines if it is to enable the young citizen to fully adapt himself to the wider environment which civilised life on its human side provides to-day.

Discussion. (Dr. R. B. Cattell.) (10.30.)

Joint Session with Section J (Psychology) on *Psychological and child guidance clinics* :—

Prof. J. Drever.—*The organisation of psychological clinics* (11.0).

Dr. D. R. MacCalman.—*The psychiatric aspect of child guidance* (11.20).

The task of a child guidance clinic is to encourage the better handling of children in general and to provide clinical care for a more highly selected group of cases rather than to accept the responsibility for the study and treatment of all children presenting behaviour problems. Any approach to the solving of personality problems must be based on an extensive understanding of the individual and on a dynamic and genetic interpretation of behaviour. The work of clinics must therefore be grounded on a knowledge of the polygenetic factors which lead to any abnormal behaviour. The clinic should be so staffed that it can deal with a wide range of educational, social and individual problems, and the task of synthesising the approach to each case has been delegated to the psychiatrist because his professional equipment ensures the most consistent orientation to the total organism.

While clinics should practise child guidance as an art, just as the physician practises the art of medicine—eclectically and with common sense—individual clinics must differ widely in their methods of treatment. Some are concerned with an attempt by various direct methods to alleviate the emotional stresses within the child ; others are more interested in treatment which involves relief from physical disorders ; while others again are more hopeful of indirect manipulation of the environment. Such clinics, however, are more than therapeutic agencies, for they gain a place in social evolution because they synthesise the most promising approaches to the problems of behaviour and personality in childhood.

Mr. Rex Knight.—*Child guidance in Aberdeen* (11.40).

The Aberdeen Child Guidance Clinic, which deals, not with mental defectives, but with ‘ difficult ’ children, was founded in April 1932 by the University Lecturers in Psychology and Education, and later its services were enriched by the co-operation of a pediatrician, nominated by the local branch of the British Medical Association, and of a psychiatrist and a social worker, nominated by the Medical Officer of Health. Nearly 100 children have been brought to the clinic, either directly by parents or on the recommendation of teachers or doctors.

The causes of their difficulties can be grouped under three main heads—physical, intellectual, and temperamental—and there has been abundant evidence of the profound, though indirect, influence that these exert on a child's thought and behaviour. It is well known that physical conditions can affect mind and character; but it must also be recognised that intellectual dullness does not result only in scholastic backwardness, but often in temperamental difficulties and misbehaviour, and, similarly, that temperamental factors can hinder intellectual growth. There have also been interesting indications of the way in which a child's family-situation affects its character, and ample proof of the fact that, in bringing up children, good intentions are not enough.

Dr. MARY M. MACTAGGART.—*Some clinical aspects of problems in learning* (12.0).

(1) Descriptive cases illustrating difficulty in learning one or more of the fundamental subjects of school instruction.

(2) Their treatment and results of treatment.

(3) A few generalisations regarding problems in learning: (*a*) significance of chance factors in failure; (*b*) the emotional effect of failure becoming the cause of increased and continued failure; (*c*) first essentials in remedial teaching.

Discussion. (Dr. C. W. KIMMINS; Dr. R. B. CATTELL.) (12.20.)

Tuesday, September 11.

JOINT SESSION with Department F* (Industrial Co-operation) on *The planning of a national policy of technical education and industrial recruitment*:—

Mr. J. W. BISPHAM.—*An administrative view* (10.0).

The adoption of a system of half-time compulsory day continuation schools up to the age of 18 would be more convenient to industry than the method of the Education Act of 1918, which required in effect only about 8 hours per week of school attendance.

The setting up of these schools could be undertaken progressively over several years and would not be in substitution for, but additional to the raising of the school-leaving age to 15 at an appropriate time. The two projects could be combined with a large consequent reduction in both juvenile and adult unemployment.

Industry also needs trained recruits from a planned system of schools which will include junior technical and senior technical schools in addition to the better-known system of secondary schools and university courses. The ideal planning of technical courses pre-supposes an exploration, by those responsible for education, of local industries — the formation of advisory committees and a full and effective liaison between those representing education and those representing industry. Lack of such liaison in the past had led to much waste of effort and to regrettable ignorance on each side of the resources available on the other.

Mr. A. P. M. Fleming, C.B.E.—*The problem in a large centralised industry* (10.25).[1]

The planning of a policy of technical education, whereby the demand and supply are qualitatively and quantitatively correlated, involves a consideration of economic and social conditions, which at the present time are in a state of flux. In these circumstances it is necessary therefore to consider the matter from fundamental principles.

An ideal system of co-ordinating demand and supply of technical workers in industry would take into account such factors as numerical requirements of every type of worker, changes in the types of production and variations in forms of industrial organisation likely to affect the numbers and types of personnel, international policies in regard to shortening hours of labour, the introduction of entirely new forms of industry, considerations such as alteration of the school leaving age, the age of retirement, etc. Could these conditions be evaluated accurately, then it might be possible to assess in advance the number and types of technical workers required and to plan their pre-industrial education, technical training and practical experience. The difficulties of such planning are obvious, and at best it is only possible to discern the general trend of industrial requirements and be sensitive to variations in demand and supply which can never be completely synchronous.

The paper indicates how a large engineering organisation representative of every type of industrial and commercial activity—research, technical design, production, sales and finance—attempts with the co-operation of the educational institutions to effect a planned system of co-ordinating demand and supply, having in mind the influence of the trend of development in types of engineering plant and apparatus, types and methods of production and markets for well-established and, as well, entirely new engineering products.

Mr. G. W. Thomson.—*The condition of technical education in Scotland from the industrial point of view ; the requirements and how they have been met* (10.50).

National planning of technical education is ahead of distributive planning of means of life. Attitude to technical education is governed by regard for industrial efficiency or the workers' welfare.

Technical educational facilities are ample for purely industrial requirements, but efficiency to which they lead raises acute problems in rendering labour superfluous. Lack of industrial opportunity discourages technical application.

Technical education, when not closely related to actual works, leads to entrance of pupils into specialised channels, and technical starvation in other directions.

Apprenticeship training is unsatisfactory and insufficient working time is allowed by employers for study. Tired students cannot benefit from class work. Vocational selection leads to problem of industrial discards.

Danger of excessive text-book training leads to inability to think and lack of initiative. Standardisation at work has bad mental effects on pupils.

Old apparatus in college laboratories and teachers lacking acquaintanceship with modern work unsatisfactory.

Evil effects of exclusive vocational training to be deplored. A claim is made to an important place for English in technical curriculum.

[1] Read by Major J. W. Buckley.

Technical training should not be divorced from cultural values, and danger of too narrow vocational selection in stratifying industrial society should be kept in view.

Mr. W. Rintoul, O.B.E.—*Technical education as applied to the training of industrial chemists* (11.15).

In dealing with the matter of training, the question arises ' Can a man be moulded into a shape like putty, or is he a diamond which requires the cutting of facets ? '

The author inclines to the latter view. It is possible for a man with a good memory to go right through, within reason, a prescribed industrial or academic course. The real question is, ' How much use is he afterwards ? ' In this country we always seek for a compromise. The paper attempts to deal with this.

Discussion. (Mr. G. A. Robinson ; Dr. C. S. Myers, C.B.E., F.R.S. ; Mr. R. D. Edmond ; Principal J. Cameron Smail, O.B.E.) (11.40.)

SECTION M.—AGRICULTURE.

Thursday, September 6.

Discussion on *Cattle rearing and feeding* (10.0) :—

Mr. J. S. Grant.—*Calf rearing or bringing out of pedigree stock.*

Mr. M. Mackie.—*The fattening of store cattle* (10.20).

An account is given of (1) the usual method of feeding in Aberdeenshire, (2) experiments in winter feeding, and (3) experiments in summer feeding.

Dr. E. S. Archibald.—*Canadian experiments on cattle rearing and feeding* (10.40).

Investigations into improved methods for rearing and feeding beef and dairy cattle have been in progress in certain parts of older Canada for forty-five years.

During this period both human and cattle populations doubled in numbers, but the opening of new agricultural areas necessitated extensive preliminary experiments as to best means for using native feeds, feeds which might be most economically introduced, by-products of manufacture, and other supplements, with associated problems of breeding, health relationship, and market requirements.

Present experiments with beef cattle deal largely with economic problems of production and finishing. A few representative investigations are :

(1) A study of age to finish in relation to modern demand for smaller cuts.

(2) Pasture and range improvements, including also mineral deficiencies, utilising surplus and low grade wheat, coarse grains, and potatoes in finishing for better quality beef at lower costs.

(3) The economics of breeding, rearing, and finishing baby beef in relation to two-year-old beef.

(4) During recent years experiments more fundamental in nature have been undertaken, including :

(5) Digestion studies of Canadian feeds as to the effect of plane of nutrition, association upon digestibility, age and digestibility, digestibility of grains as affected by roughages, and feeds as affecting meat flavour.

Prof. R. RAE.—*Systems of rearing and feeding for the production of young beef* (11.10).

The animals for the investigation were calves, the progeny of cross-bred Galloway cows mated with a pedigree white Shorthorn bull. All calves were weighed at birth, at weaning and at date of sale or slaughter. The direct costs of production for each group of animals fattened were ascertained and are expressed both as cost per head and cost per cwt. live weight.

Five groups of calves were obtained over a period of three years. In all groups the calves suckled their dams for approximately six months, but thereafter the system adopted varied for the various groups. Spring-born calves were housed in the autumn and sold fat in the beginning of the following June at an age of 14 months. Summer-born calves were wintered cheaply after weaning, turned out to grass in spring, housed from September, and sold fat at Christmas at an average age of 18 months. One group was sold as forward stores at 10 months old. The last group, March-born calves, were wintered cheaply, but without allowing condition to be lost, and then turned out to grass in the spring. They were sold fat off the grass during summer at an age of 16–17 months.

The paper is concerned with a description of the systems of rearing and feeding adopted and a discussion of the results.

Mr. H. J. PAGE, M.B.E., and Dr. S. J. WATSON.—*Fodder conservation and its place on the farm* (11.30).

Hay-making is the method of conservation in general use. The losses involved are surprisingly high, up to 50 per cent. of the starch equivalent in the fresh grass being lost as a result of respiration, mechanical losses in the field and fermentation in the stack, and even under ideal conditions the loss may be 33 per cent. The loss of digestible protein is of a similar order. Artificial drying is the ideal method of conservation, the retention of protein being almost complete, whilst that of starch equivalent does not fall far behind. The losses involved in silage-making when properly carried out are less than is the case with hay, but with badly made silage, especially in the stack, they may equal or even exceed the losses in hay-making. Under British conditions the addition of mineral acids does not appear to give a marked reduction in the loss of starch equivalent, in comparison with ordinary or molasses silage, made with equal care, but it prevents the break-down of protein which is characteristic of ordinary methods of making silage and makes the control of the fermentation more certain.

Artificially dried grass and well-made silage retain the carotinoid pigments of the fresh crop in a large measure. This is particularly true of dried grass and A.I.V. fodder.

The inclusion of carotene-rich foods of this type in the ration of the dairy cow results in the production of a milk with a fat of high yellow colour reminiscent of that of pasture-fed cows. This yellow colour is a function of the carotene content and is correlated with the vitamin A content of the milk.

The fat in the milk of different breeds of cows varies in regard to the depth of colour produced on the same ration, though for any one breed there is still a correlation between colour or carotene content and vitamin A potency.

If practical and economic methods of drying or ensiling (or both) can be developed, this should open up the possibility of feeding stock in winter, for production as well as for maintenance, mainly on home-produced foodstuffs. The way in which such processes could be embodied in the ordinary management of grassland is discussed.

Discussion (11.50).

AFTERNOON.

Visit to the Macaulay Institute for Soil Research, Craigiebuckler.

Friday, September 7.

JOINT SYMPOSIUM with Section I (Physiology, *q.v.*) on *Nutrition in relation to disease* (10.0).

AFTERNOON.

Visit to the Craibstone Experimental Farm, North of Scotland College of Agriculture.

PUBLIC LECTURE by Prof. J. A. S. WATSON on *Science and the animal industry* (3.30).

Saturday, September 8.

Excursion to Collynie, Cruden Bay, Port Erroll and Grandhome.

Monday, September 10.

PRESIDENTIAL ADDRESS by Prof. J. A. S. WATSON on *Scientific progress and economic planning in relation to agriculture and rural life* (10.0). (See p. 223.)

Sir A. D. HALL, K.C.B., F.R.S.—*The planning of agricultural production* (10.50).

The competition set up by intensive nationalism has destroyed the economic position of the British farmer. Hence the nation has abandoned its old policy of Free Trade and has adopted various measures for the protection of agriculture. At the same time it is recognised that internal competition alone, in which imports play but a small part, may be equally destructive of the stability of the industry, checking enterprise and that development of production which is needed by the nation. This is the case for a planned agriculture which aims at organising the farming community and the dependent processing and distributive trades, in order to extend and cheapen the output from our own land. The Marketing Boards that have been set up for the various commodities, in virtue of their monopoly, can direct the production along the lines that are most economic and

best suited to the requirements of the consumer. But it is an implied condition of this monopoly that while it ensures adequate returns to the farmers it will call for a corresponding response from them by the adoption of improved methods. With milk, for example, it will be possible to improve the quality and cleanliness and to eliminate the risks of the dissemination of bovine tuberculosis and other diseases. With meat, again, proper organisation should be able to grade up the quality of British meat by better methods of slaughter and management to put it before the public in the excellent condition that characterises much of the imported meat. While the best grades of British meat are pre-eminent, a large proportion of the output has latterly been unsaleable. Ultimately the planning will require a consideration of the relative claims to development of the various products of the farmer. At the best Britain can only produce a proportion of the food it consumes, and a selection should be made in favour of those products best suited to our climate and soil and calling for labour and skill—milk and live stock products, vegetables and fruit, for example, as compared with the cheap wheat and sugar. At the same time, even for such products consideration has to be given to the specific capacities of particular areas. The new organisation presents many difficulties, only to be overcome by a process of trial and error.

Mr. A. McCallum.—*The diffusion of scientific knowledge to the farmer in Scotland* (11.20).

More than two hundred years ago the problem of diffusing knowledge to Scottish farmers was exercising the minds of progressive landlords and others. Many landed gentlemen demonstrated new methods on their own holdings. The Society of Improvers, formed in 1723, acted as a pool of farming knowledge and as an advisory body. A later association stimulated improvement by the offer of various premiums. At the end of the eighteenth century the Highland Society took the lead in promoting agricultural improvement by premiums, exhibitions and publications, and by fostering agricultural education and helping the establishment of the Chair of Agriculture at Edinburgh.

The rise of instructional centres at Edinburgh, Aberdeen and Glasgow was consequent on the distinctive characters of the farming in the three provinces.

The predominant feature of Scottish farming being animal husbandry, the main lines of research undertaken deal with nutrition, breeding, diseases, and milk production, but soils and plant-breeding have provision made for them.

In the curriculum of general education more time should be found for the study of biology.

Only a small proportion of the farming community can be directly affected by central teaching, and for the majority the important part of the organisation is the county staff.

Prof. W. G. S. Adams.—*Better living : the community movement in the countryside* (11.40).

Discussion on *Science and rural life* (12.0).

Afternoon.

Visit to the Rowett Research Institute, Bucksburn.

Tuesday, September 11.

JOINT DISCUSSION with Section B (Chemistry, *q.v.*) on *The chemistry of milk* (10.0).

JOINT DISCUSSION with Section K (Botany) and Department K* (Forestry) on *Soil and ecological studies in relation to forestry and grazing* (10.0) :—

Dr. W. G. OGG.—*Introduction.*

About four-fifths of the total surface of Scotland consists of uncultivated ground. Much of this land on account of altitude and steepness of slope is unsuitable for cultivation, but great areas are not being used at present to the best advantage. More could be done in the utilisation of such land for forestry and grazing purposes, and in recent years increasing attention has been given to this work particularly by the Forestry Commission. It is important that the improvements should be carried out along the best lines and two aims should be kept in view :

(1) The use of the land for the purpose for which it is best suited.

(2) The improvement of the land by various methods of treatment at an economical cost.

The soil investigator and the ecologist can render useful assistance in attaining these objects. It has been found that a study of the soil profile and the vegetation often gives the necessary clues to solving the problems encountered. The appearance of the various soil layers gives indications as to drainage conditions and fertility. The occurrence of hard pan has a direct bearing on the uses to which a soil can be put ; and a close connection has been found between the natural vegetation and the soil type.

Dr. A. S. WATT.—*The ecologist and land utilisation* (10.10).

Dr. A. MUIR.—*Forest soils* (10.30).

Under the prevailing climatic conditions the predominant feature of the soil-forming processes is a leaching of mineral substances from the upper soil layers, with the subsequent precipitation of some of these in the lower layers, the others being completely removed from the soil in the drainage water. Where the soil parent material is poor in basic substances, the effect of this leaching soon becomes apparent in the upper layers. Such soils are known as podzolised soils, their characteristic feature being the presence of an ashy grey layer underlying the layer cf organic residues. When the soil parent material is rich in bases the effects of leaching are not so apparent, and the soil profile is of a more or less uniform colour. This same characteristic is often a feature of soils on steep hill slopes. The precipitation of the leached substances, especially iron and alumina, leads to the formation of a very compact and cemented layer, which sometimes is so hard that roots and water fail to pass through. When this happens, fundamental changes take place in the soil profile. The layers above the hard pan become water-logged ; the lack of air gives rise to reduction processes, and the soil becomes invaded by an inferior type of vegetation. When this happens, peat formation sets in. In many soils a high ground water level may have the same effect.

When the soil has already borne a good forest crop, probably very little

treatment is necessary. Old drains may require cleaning, but the soil is usually in good condition.

In land which has not already carried a forest crop, wide variations of soil type are to be found, and it is in this case that a study of soil conditions from the genetic standpoint may prove very useful.

On steep slopes drainage is usually sufficiently good to preclude the cutting of drains, but in regions of high rainfall peat formation sets in very quickly, with the result that some draining is often necessary.

On the flatter ground draining is usually an essential operation, and in some cases the only one necessary. In other cases even draining is not sufficient, and the application of some manure is necessary to prevent the young plants from going into check.

When a hard pan is present it is desirable but not always possible to break it. This may be done by deep ploughing. When the pan cannot be reached by the plough, ordinary ploughing may give rise to sufficient aeration so that the pan becomes soft enough to allow the tree roots to pass.

Dr. G. K. Fraser.—*Peats and peaty soils* (10.50).

True peat soils in Britain belong to two main groups : (i) Topographical or Basin Peats, which develop in areas of high ground water or of free stagnant water ; (ii) Climatic Peats, which are alpine in Britain as a whole but form the normal soils under the high rainfall of the north and west of Scotland, the organic soil forming above not only high ground water profiles such as gley, but also on drier profiles such as sand podzols.

In Scotland, the climax vegetation of these types is characterised by a mixture of *Scirpus cæspitosus* and *Calluna vulgaris*, with a moss layer in which the *Sphagna Acutifolia* group predominates. This climax is reached in the east of Scotland as a rule only on ancient peats of early post-glacial origin, but under the high rainfall of the west it develops on moderately shallow peat of recent origin.

Although very poor in available nutrients, the chief disability of these peats is insufficient aeration. The peat of the west of Scotland is less tractable than that of the east, since it is more highly dispersed and more plastic, and therefore less easily drained and less easily penetrated by manures. It therefore requires either very intense or very prolonged measures of amelioration for its improvement.

Mr. E. Wyllie Fenton.—*Some aspects of the influence of grazing on vegetation* (11.10).

There are few acres of vegetation in Britain which are not affected by the grazing factor. When grassland or arable land is left derelict—and no grazing occurs—it sooner or later reverts to wood, scrub, or heath. The nature and extent of grazing definitely affects the vegetation. Of all animals probably goats are the most destructive as far as scrub or woodland is concerned. Among wild animals, deer and rabbits are the most destructive, but damage by mice, squirrels, birds, caterpillars and grubs must not be forgotten.

The indirect influence of grazing is very important, such as burning moors and rough grazings, since under such conditions regeneration of trees is practically impossible. The replacing of cattle by sheep on many of the hill grazings of Scotland has much to do with the spread and increase of bracken. The indiscriminate destruction of the original vegetation has

often had deplorable results. Damage by grazing of various kinds often leads to diseases which may prove far more serious.

The balance of nature is often upset, and there is still much to be learned concerning this problem. The obtaining of further information of the relationship of plants and animals offers a good field for the advancement of knowledge.

Discussion. (Sir JOHN RUSSELL, F.R.S.) (11.30.)

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

The Conference was held at Marischal College, Aberdeen, on September 6 and 11, under the Presidency of Col. Sir Henry Lyons, D.Sc., F.R.S., and was attended by 44 delegates representing 49 societies, in addition to a large audience.

Thursday, September 6.

ADDRESS ON

SCIENTIFIC SOCIETIES AND MUSEUMS

By Col. Sir Henry G. Lyons, D.Sc., F.R.S., President of the Conference.

The field of scientific activity covered by the Societies which are represented here to-day is so wide that an address on almost any subject might be considered to be appropriate to their interests ; and in fact, when I look at those that have been delivered of late years, I can discover no definite trend in them, other than the desire to contribute to the advancement of the knowledge of science and its applications. And this is as it should be ; we should address our colleagues on those subjects of which we have personal knowledge and can speak from practical experience.

For the last twenty years I have been occupied not so much with any particular branch of science as with making available to others scientific and technical information of various kinds ; and that by display and exhibition rather than by writing. In this task it has been brought home to me very vividly the need that there is for fuller organisation in this field, how large are the resources which are in existence and how real the difficulties which workers may experience in gaining access to them. The problem, which is familiar to every student of any branch of knowledge—that the piece of information for which A is seeking is often a commonplace to B, but there is no connecting agency to bring them together—still remains for the great majority but very imperfectly solved. Bibliographies have multiplied and are multiplying in every subject, until they now form an important section in a library of any size ; efficient and rapid handling of them is becoming a specialised side of the librarian's work.

At the same time steady progress is being made in several directions, and in none do I see more hopeful prospect than in the co-operation of the three classes of institution which have already done so much to this end—I refer to the scientific society, the library and the museum. Each of these has its own special mode of distributing information—by discussion, by books and other publications and by display—and they offer much to the scientific student and worker who does not perhaps always utilise them to the full extent, or who may not know the assistance that they can render to his special needs.

One reason that suggested itself for taking this subject for my address to-day, is that many firms in technical industry at the present time are employing to an increasing extent scientifically trained men in their research departments, to whom a ready access to current technical literature is all-important, and it is hardly to be expected that this is to be found to hand everywhere, nor is it worth while to accumulate technical periodical literature which may be but rarely required.

Again, discussion on scientific and technical subjects, which is readily obtainable in London and in the large cities, may be less easy to arrange for elsewhere. It is not only with workers in the same field that such discussion may be fertile in results ; in other lines of investigation methods evolved for other purposes may often be usefully taken over and adopted.

Dr. George Hale of Mount Wilson Observatory, California, during his presidency of the International Council of Scientific Unions, has drawn attention to many cases within his own experience when instruments and methods which were perfectly familiar to workers in one branch of science were wholly unused by investigators in other fields, and gave as an illustration a case at Mount Wilson Observatory in which the range of the 100-inch telescope has recently been increased 50 per cent. by the adoption in its spectrographs of a new type of photographic objective, developed on the principle of a microscope objective by Mr. Rayton of the Bausch and Lomb Optical Company. This has made possible the measurement of the enormous velocities of the extremely remote spiral nebulæ which have been used in recent discussions on the Expansion of the Universe.

More recently the British Scientific Instruments Research Association has made further suggestions which are expected to increase very considerably the anticipated efficiency of the 200-inch telescope which is now under construction.

He emphasises the point that such helpful suggestions may come from the most unexpected quarters ; and there is no reason why similar consultative co-operation by the workers of a single locality in various fields of science may not be quite as helpful to them as it is anticipated that it will be in the international field.

In recent years much has been done to improve and to extend the influence of local museums, and in this movement no one has done more than Sir Henry Miers ; as a result many of them now exercise a valuable influence in many fields. In the past they have in many cases received their main support and encouragement from those who were interested in Archæology and Natural History, and Science and Technology could only find place in the larger institutions. But now many of them are giving much attention to the representation of the technical industries which have been established in their vicinity and to the display of the scientific principles on which they are based. Such institutions are exceptionally favourably situated for securing those early examples illustrating the path of development which has been followed in arriving at the efficiency of to-day, and which are becoming scarcer every year.

In this direction steady advance is being made, and we may note with special interest the opening six weeks ago of the Municipal Museum of Science and Industry at Newcastle-upon-Tyne, where the scientific and industrial advances which have been made in this district will be illustrated, and future progress recorded. The existence of an active and influential body, the North-East Coast Institution of Engineers and Shipbuilders, to assist and guide its efforts is a guarantee that its development will be rapid and that it will be of real value and interest to all who are engaged in scientific and technical work in the North of England.

Museums can hardly assist the research worker to the same extent that societies and libraries can, since museum display must confine itself mainly to providing an informative exhibit of what has been attained in this branch of science or in that industry ; but the growing practice of arranging temporary exhibitions to illustrate a special activity or achievement may be expected to provide matter of interest to him, and should also enlist his interest and resourcefulness in making such exhibitions both interesting and representative of the latest advances in the subject.

Archæology and natural history take a prominent place in the activities of many local societies, but there seems to be no reason why those who have so restricted their interest should not also co-operate with their museum in representing not only local trades but also those modern industries which are growing rapidly around them. In bringing such technical processes and products to the notice of the public, the modern museum has a task of great importance and one with which it is specially competent to deal. Even though the subject may present difficulties and the processes may be complicated, it is quite possible to make them fully intelligible to visitors ; and if such an exhibit is understood the visitor is at once interested. The experience gained at the Science Museum, London, during the past ten or twelve years has shown very clearly that trouble taken to make scientific exhibits intelligible is well spent, for once they are understood they arouse a keen interest in the minds of visitors, which is far more effective in inducing others to come in their turn than any form of advertising which can be planned.

But however attractive an exhibit may be, it will sooner or later become too familiar to arrest the visitor's attention, and the museum which is the most visited is that which the public regard as usually having something new for them to see. Here the members of a society may assist the curator by their suggestions, as well as by arousing the interest of those who may be in a position to contribute objects of special technical interest.

Among libraries co-operation has already advanced far, and through the National Central Library local libraries can obtain for their readers access to far wider and more specialised collections of material than can be found at any one place out of London. Here scientific workers, and especially those who are engaged in research work for industrial purposes, are in a somewhat special position, for often they require published material not so much for lengthy study as to look through in order to see what is being done in some special branch elsewhere and in other countries ; a reference given in a technical journal may have to be followed up ; while not infrequently time is of considerable importance and everyone cannot expect to have at his elbow a technical library equipped to provide both foreign and home publications on a large scale. But now, through the facilities provided by the National Central Library and by the Science Library at the Science Museum, London, where there is one of the largest collections of periodical scientific and technical literature in existence, he can obtain on loan what he requires for a sufficient time to enable him to see what it contains of importance for his purpose. In this way, not only may the costly duplication of published material be avoided, but also needless waste of time in following up a line of investigation which has already been worked out elsewhere may be prevented. The rich bibliographical equipment at these libraries also enables them to indicate where recent information on various subjects in many lands may have appeared, and inquiries of this kind are readily answered so far as the resources of the institution allow.

The access to published subject matter in the field of pure and applied science is to-day fairly easy to all, though this is not so generally realised

as it should be. The Report of the Advisory Council of the Science Museum, London, which has just been published, states that issues of books, etc., from the Science Library to external readers during 1933 exceeded 16,000, an increase of 3,000 on the previous year; but this seems to be a very small drain on its resources when we learn that the number of current scientific and technical periodicals which are being regularly received there is 8,696, while the stock of the library now numbers some 230,000 volumes, dealing with almost every branch of science and technology except medicine. The card-index to subjects contains now nearly two million references. Here, at any rate, is an inexhaustible source of information for the investigator in industrial research, of which he can with profit make use to a far greater extent than has hitherto been the case.

It would seem, therefore, that in most cases there should not be any great difficulty in facilitating the acquisition of information needed by scientific workers in any part of this country if local resources are utilised, and the necessary enthusiasm is forthcoming. The technical matters which research workers may wish to discuss will not always be attractive to some of the members of the scientific society concerned, but perhaps special meetings for this purpose could be arranged. Some thirty years ago meetings of this kind at a small scientific society, Cairo, where technical libraries were then non-existent, proved to be of the greatest value to its members, who at them exchanged views, acquired information over a much wider field than that in which their own activity lay, and brought out many pieces of information which otherwise would never have come to light, and which later developed into scientific records of permanent value.

However, reliable and well-planned accounts of the direction in which modern science is advancing are always acceptable and can be made to be extremely interesting, even to those who may have no special knowledge of the subject.

The larger part that science is playing and must increasingly play in industrial progress, as well as that understanding of the relations between the advance of science and the life of the community which this meeting of the Association is specially emphasising, provides for scientific societies throughout the country a wide and fertile field of endeavour, and in this task they will find that both their museums and their public libraries will be able to render most valuable assistance, each in its own sphere.

Prof. P. G. H. Boswell, O.B.E., F.R.S.—*Town and country planning schemes in relation to sites of scientific importance.*

Under the Town and Country Planning Act, 1932, a local authority or joint committee must obtain the approval of the Minister of Health to a resolution deciding to prepare a scheme. Among the objects of such a planning scheme, as cited in Section 1 of the Act, are ' preserving existing buildings or other objects of architectural, historic and artistic interest and places of natural interest or beauty, and generally of protecting existing amenities whether in urban or rural portions of the area.' Arrangements have now been made under which the Ministry of Health is systematically notifying the British Association of the areas in which planning schemes are proposed. The Association is well fitted by its aims and constitution, and by its liaison with its Corresponding Societies, to make representations when necessary to the Ministry and to appropriate local authorities or joint committees for the preservation of sites or objects of exceptional scientific interest—botanical, zoological, geological, birthplaces or domiciles of

scientific worthies, and so forth. Obviously, the Association must rely largely on its Corresponding Societies for information as to sites or objects which may be endangered. Suggestions are therefore invited from the Delegates as to the best method of procedure for obtaining information as to sites, etc., which should be preserved.

Sir Albert E. Kitson, C.M.G., C.B.E.—*The necessity of recording well-sinkings and borings for water.*

The supply of information respecting the nature of strata found during boring operations, and the bearing of such on water supplies, is admittedly highly desirable. But registration of such information is not legally compulsory.

Boring operations for water afford excellent opportunities to obtain this information, and it is advisable to do so. It has been urged that people actually operating the boring plants are not geologists, and so cannot give particulars of value. This is erroneous ; they can give the main results, leaving the details of strata to be supplied by geologists.

The Geological Survey of Great Britain has done and is doing most valuable work in this as in all other sections of geology and can supplement such information. The numerous activities of this and other kinds in this country, as for instance those of the recent drought, afford good opportunities in this direction, but it is only possible for the Geological Survey to arrange for visits to boring operations if informed of them. There are, besides, large numbers of devoted non-professional geologists, widely dispersed throughout this country, who can safely be depended upon to assist in the matter. Further, the members of Corresponding Societies can also assist by notifying the Geological Survey of any such operations in their districts.

Co-operation and co-ordination in this manner will give valuable information—at present only obtainable in some cases—and be of great economic value to us.

Tuesday, September 11.

Afternoon (2.0).

Prof. F. G. Baily.—*National Parks for Scotland.*

A National Park in Scotland should contain some 200 square miles of mountain and moorland, glens and woods, lochs and rivers, with a dry climate. The primary object is to provide holiday ground among the hills, available to the public all over and at all times. Accommodation at low cost should be provided by huts, boarding houses, and camping grounds, that many classes of people who at present cannot afford a Highland holiday might enjoy a week or two. The Park should be under the control of a trust, rather than a government department, local representatives keeping in touch with the management. The area should be easily accessible from the towns, but not so near as to permit of day trips, which would introduce difficulties of control. The expense of running the Park, some £5,000 a year, should be provided by the burghs and the Treasury. The Park would function also as a reserve for wild fauna, but under control by the wardens as to birds and beasts of prey, and suitable numbers of deer. The Cairngorm *massif* is suggested as fulfilling the requirements most nearly.

NATIONAL PARKS

By P. Thomsen, M.A.

The paper which I am to have the honour of reading to you will deal with the question of National Parks in Scotland as part of the larger question of National Parks in Britain ; in my opinion no other treatment can be satisfactory. Further, all my conclusions will rest on the assumption that contact with beauty, on a large scale, such as Nature, untouched by man, can alone supply, is of the greatest importance for the development of the highest human qualities. If this be granted, as I think it will, it follows that we have no right to deprive posterity of the means of such contact, but that natural beauty, the slow growth of thousands of years of geological and botanic action, must be jealously guarded as an irreplaceable national asset. It follows, in short, that we must set aside areas, to be called National Parks, in which the preservation of natural beauty and its free enjoyment by all as a matter of right, shall be the dominating principle of administration.

If the need of such action be admitted, it will also be admitted that there is need of haste. The forces which, in the name of progress, tend to the destruction of natural beauty, are relentless, and, thanks to the enormous concentrations of capital which they can now command, work with ever-increasing speed and power. And if practical difficulties debar us from the immediate execution of our whole plans, we can at least see to it that these plans are ample enough to bear some relation to the importance of their object and the greatness of the nation for which they are designed, and that machinery which will ensure their ultimate accomplishment is brought into being.

Such plans I shall endeavour to lay before you.

Extent of National Parks.

The method by which National Parks should be secured, and the machinery for their development and administration depend largely on their extent. Before proceeding to these other matters therefore, it is necessary to decide, at least tentatively, what is the total area of National Park land which Britain should endeavour ultimately to possess.

The principal factor to be considered is the magnitude of the population which the National Parks are intended to serve. Looking to other countries in which a National Park policy has been long established and approved, we find as follows :—

1. *U.S.A.* (1932) :

Area of National Parks (not including State Parks or Forest Reserves)	20,247 sq. miles.
Population	126 millions.
Park land per million inhabitants	161 sq. miles.

2. *Canada :*

Area of National Parks (not including Provincial Parks)	12,000 sq. miles.
Population	10 millions.
Park land per million inhabitants	1,200 sq. miles.

3. *New Zealand:*

Area of National Parks . . .	4,500 sq. miles.
Population	$1\frac{1}{2}$ millions.
Park land per million inhabitants . .	3,000 sq. miles.

It is admitted that Canada and New Zealand are still in the infancy of their development; yet such an increase in population as would bring their Park allowance down to the U.S. figure, is not reasonably in sight. In the case of the U.S. itself, while the population is undoubtedly still increasing, so is the area of the National Parks, and that at a more rapid rate than the population, the details being these :—

	Increase 1920–1930.	Increase 1920–1932.
U.S. Population	16 per cent.	19 per cent. (estimated).
U.S. National Park	27 per cent.	53 per cent.

There is therefore no good reason for anticipating any fall in the Park allowance figure already given for the U.S.A.

4. *The State of New York*, considered as a separate political entity, offers, however, the closest possible parallel to Great Britain. Its area, its population, and the density of its population, though smaller, are all of the same order of magnitude as those of Great Britain. It has one very large city, and generally is highly urbanised, 84 per cent. of its inhabitants being classed as urban. Its inhabitants have the same rights in the National Parks proper as other U.S. citizens, but, in addition, it owns and administers State Parks with a total area of about 3,700 sq. miles, which for a population of $12\frac{1}{2}$ millions, gives for each million inhabitants an area of 295 *sq. miles*.

If we take the lowest of all these figures, namely that pertaining to the whole U.S., 161 sq. miles per million inhabitants, as the minimum which an enlightened regard for the claims of posterity can allow us to contemplate as our ultimate objective, we should have for Britain's 45 million inhabitants a total area of 7,245 sq. miles. The policy of the present generation might be restricted to a figure of, say,

6,000 *sq. miles*.

It may be noted that this is $\frac{1}{15}$ of the whole area of Britain; the State Parks of New York State extend to $\frac{1}{13}$ of the whole area of that State.

Objections.

The Report of the Committee on National Parks (1931) objects to comparisons with the United States on the ground that Britain is 'small, densely populated and highly developed, and has relatively little land which is not already put to some economic or productive use.' These objections do not seem to be well founded. The size of a country is in itself quite irrelevant to the issue, except in so far as it affects accessibility; and in that respect it tells in favour of the smaller country. Again, its high density of population is all in favour of a large reservation for Britain; the greater the density the more completely urbanised will the general aspect of the country be, and the greater will be the need of the population for occasional contact with Nature in its pristine beauty. The relatively smaller area in Britain not already devoted to productive use is relevant only if it involves an absolute lack of areas of sufficient size and natural beauty to serve as National Parks, and to that point we shall now address ourselves.

Availability of Areas.

For the purposes of National Parks Britain must be considered as a single unit. There are no obstacles to travel between England, Wales and Scotland. The Scottish Highlands are as accessible from the Midland towns as are the South Downs or the New Forest or Dartmoor. The distance even from London to Fort Augustus is to-day of no great consequence, and will become negligible with the improved transport and greater leisure of succeeding ages. It is therefore reasonable to suppose that in selecting the sites of the National Parks, political boundaries will be ignored, and attention given only to the sublimity or beauty of the scenery, to its untouched condition, to the ease with which it may be acquired, and, finally, to as nearly as possible an even geographical distribution of the Park land throughout the kingdom. On this basis it may be fairly assumed that of the 6,000 sq. miles which we have claimed, 2,000 sq. miles will be allotted to Scotland, and 4,000 sq. miles to England and Wales.

Now, in Scotland, the area under permanent grass, rough grazing, moors and forests extends to 23,800 sq. miles, including over 5,000 sq. miles of deer forest and grouse moor. In Scotland therefore there will be no difficulty in securing the stipulated 2,000 sq. miles.

In England and Wales the problem is rather more difficult. It is true that the area under permanent grass, moors and forests amounts to 30,300 sq. miles, but much of this land lacks the beauty which is the first requisite of a National Park. It is, however, quite consistent with our original premises to include in our National Park System land already partially or even fully developed, so long as further development, if any, is nationally controlled solely in the interests of amenity. On this basis the Lake District might yield about 700 sq. miles. In the stricter sense, implying actual possession, the Peak might yield about 200 sq. miles of National Park, and the Yorkshire moors anything between 400 and 800 sq. miles. If we add to these some considerable part of the English Commons (in so far as not already included) which themselves extend to 2,500 sq. miles, the Forest of Dean, the New Forest, Snowdonia and other parts of Wales, parts of the South Downs, the Cotswolds, the Malvern Hills and of the thirty other regions which were brought to the notice of the Committee on National Parks, it will be abundantly clear that there is still room in England and Wales for a system of National Parks extending to 4,000 sq. miles, and that too without any material interference with the economic life of the country. I adhere therefore to my original figure of 6,000 sq. miles, being 2,000 sq. miles in Scotland and 4,000 sq. miles in England and Wales.

Administration.

The control or acquisition, development and protection of so great an area is obviously an undertaking too great for local authorities, either singly or in combination, and still more so for semi-private bodies such as the National Trusts. It will be necessary to constitute by Act of Parliament a new Government Department which may be called the National Park Commission. For reasons which will appear presently, its permanent head should be the chief commissioner for Crown Lands ; other members, possibly to the number of 8 or 10, shall hold office for five years ; two shall be appointed by the Government of the day, and the rest shall be nominated by suitable English, Scottish and Welsh Associations designated in the Act.

Procedure.

The Commission shall be empowered by the Act which brings it into being, to hold surveys, and thereafter, subject to Parliamentary approval, to schedule lands for preservation as National Parks. Lands so scheduled shall become subject to the jurisdiction of the Commission in three progressive stages.

1. The first stage shall aim merely at the preservation of the *status quo*. There shall be no interference with sporting rights, nor with agriculture as existing at the time when the area was scheduled. Right of access shall remain as it was. But the Commission shall hold, and if need be exercise, a simple veto on all developments which would, in their opinion, affect the beauty of the area. Thus the cutting of timber, especially old timber, the damming of rivers and lochs for hydro-electric or other purposes, the diversion of roads, and the initiation of industrial activities of a disfiguring nature, shall be prohibited. Except possibly in connection with the conservation of timber, no compensation shall at this stage be payable to the proprietors of the scheduled area.

2. The second stage shall be the stage of limited access, i.e., access by certain routes and at certain seasons. With a view of such access the Commission shall have power, after adequate notice, to construct new roads, to build and maintain rest houses, to organise camping sites. Compensation may now become payable to the proprietor. It may, in whole or part, take the form of payment of maintenance costs, and relief from local and national taxation including death duties. The amount of compensation shall be settled by methods to be prescribed in the Act.

3. The third stage shall be full possession following upon purchase. Any sums previously paid by way of compensation shall be reckoned as part of the purchase price.

Some of the advantages of such procedure are both great and obvious.

1. It would be possible to give immediate protection of a simple kind to a very large area.

2. If industrial development or other defacement within a scheduled area should be proposed, the onus of proof would rest upon the proposers, i.e., they would require to prove that the economic gain to the Nation arising out of their proposals outweighed the loss arising out of the destruction of amenity, in such a degree as to justify Parliament in over-riding the decision of the Commission.

3. The defence against such encroachment would be undertaken by the Commission backed by the whole wealth of the Treasury. At present it is left to local Authorities, whose views may be warped by local financial stringency, and to those individuals (and those only) who have local proprietory interests. The legal expenses are heavy and irrecoverable. The tendency obviously is for opponents to yield to financial intimidation and to withdraw their opposition. The case of the Nation then goes by default. With the Commission in charge of the defence no such situation could arise.

Finance.

If the action of the Commission were to be limited to the first of the three stages set forth above, i.e., to scheduling lands for preservation in their existing condition, no great annual outlays would be required. It is obvious, however, that preservation without ultimate access would be inconsistent with our whole conception of a National Park, and as soon as the question of increased access arises, the question of compensation and finally of purchase price, arises with it.

How much, then, would it be reasonable to expect that the British Nation, acting through its Government, should set aside annually with a view to securing the benefits of a National Park system to its own posterity during the illimitable future? The answer will not affect our decision as to the area which would be reasonably sufficient, but it will affect the time which must elapse before that area can be brought into full usefulness.

It is admittedly difficult to fix a definite figure for expenditure in a new enterprise. The Parliamentary Committee of 1931 hesitated between a Government expenditure of £10,000 and £100,000 per annum, with a leaning towards the higher figure. The wide divergence between these two figures seems to indicate that neither was founded upon a reasoned basis. Perhaps the best that can be done is once more to endeavour to profit by the experience of other countries in which the enterprise is no longer new, studying their figures with suitable modifications for economic differences.

You will, I fear, not tolerate the Canadian practice in this matter. In the financial year 1932–33 Canada expended $1,100,000 on her National Parks. According to reputable statistics the national wealth of Britain is about 4½ times that of Canada. On the Canadian standard, therefore, we should be prepared to spend $5,000,000, say £1,000,000 annually for National Park purposes.

Personally, I think that for a nation with an annual income of £3/4,000 million, this expenditure would be not unreasonable. But I fear that even in this meeting I should find little support for such views.

Let us turn therefore to the United States.

The United States has had over sixty years of experience of National Parks. During this period there have been trying times, and several changes of government; but public opinion has never wavered in its support of National Parks. The annual appropriations by Congress for their maintenance and development have risen from $784,567 in 1917, when the Parks were taken over from the several States by the Federal Government, to $10,640,620 in 1933. The total for these seventeen years is $72,304,000. This by no means represents the whole cost of their National Parks to the American people; many millions of dollars have been subscribed for Park purposes by private individuals and by the State Legislatures; but it does represent the whole cash contribution of the Central U.S. Government to the Parks during these seventeen years, and it is Government contributions with which we are at present concerned. The average annual outlay has been $4,253,000, equivalent at par exchange to £880,000.

This figure also must be modified to allow for economic differences. At least two different sets of figures with authoritative support point to the conclusion that the total wealth of Britain is about one-third of that of the United States. American experience suggests therefore that for Britain an average expenditure of £300,000 per annum would not be excessive. This is very nearly the sum originally allowed to the Forestry Commission—another new State enterprise having many points of affinity with a National Park Service. On the strength of that precedent, coupled with the analogies already adduced, I hold that we should claim for our National Park Service, provision equal to that originally made for our National Forest Service, namely an annual grant of £350,000.

To bring this claim into true perspective within the national economy it is desirable to recall such facts as these:—

1. Since the War the beet sugar industry has received grants totalling over £40 million.

2. Certain shipping concerns have recently been promised a grant of £9½ million to enable them to engage in a highly speculative undertaking.

3. The nation spends nationally and locally over £100 million per annum on Education. National Parks may well be regarded as a means of education in the widest sense of the word, and the suggested grant would be equivalent to the addition of less than a penny to every pound already spent on Education.

4. The proposed grant is the yield of less than half a farthing in the standard rate of Income Tax. The recent budget has reduced the standard rate by sixpence.

Moreover there will be considerable returns to set against the expenditure. Much of it will be incurred in road-making, in drainage and other improvements within the selected areas, and will thus, by the provision of new useful work, help to save the Unemployment Fund. The rest, used for compensation or purchase, will be represented by an increased area of Crown Lands.

Nor must it be forgotten, that, while the chief object of the National Parks will be to promote the physical and spiritual well-being of our own people, they would also incidentally be a great attraction to tourists. According to a recent analysis by Professor Ogilvie, on balancing the amount spent by foreign tourists in Britain against the amount spent by British tourists abroad, there is a net loss to Britain of £10 million annually. It is not reasonably open to doubt that, with a good system of British National Parks in actual operation, that loss would be considerably reduced.

From every point of view therefore the expenditure of £350,000 a year is easily justifiable.

Source of the Money.

Economically it matters not at all what is the immediate source of this money. But politically it may matter very considerably. I suggest that the minimum of political opposition would be encountered if the proposed grant for the National Park Service came directly out of the surplus accruing annually from existing Crown Lands. For many years this surplus has amounted to over £1,000,000; in each of the last two years it was £1,250,000; hitherto it has simply been paid into the Treasury for general purposes. Nothing could be more appropriate than that part of it, at least, should be used for extending the area of the Crown Lands. The Act which brings the National Park system into being should therefore provide that the Commissioners of Crown Lands shall, out of their annual profits, pay an agreed sum (such as £350,000) into a special fund to be used by the National Park Commission for the purposes of the Act. Unexpended sums to be accumulated in the Fund, and not to be attachable by the Treasury for other purposes.

Lands purchased by the Commission should be vested in the Crown but administered by the Commission.

The Chief Commissioner of Crown Lands should be Chairman of the National Parks Commission.

The Commission should also have borrowing powers on the security of their annual grant.

Results.

On the assumption that one-third of the proposed annual income of the Commission is earmarked for Scotland, and that, on average, one-third of this sum is used for administrative expenses and for development, there will remain about £80,000 annually for the purpose of land purchase in Scotland. Several independent lines of evidence lead to the conclusion

that land of the nature which would be required for National Parks can be purchased in Scotland for £1 or 25s. per acre—say 30s. an acre at most or £1,000 per sq. mile. At this price the 2,000 sq. miles which has been suggested as a suitable allocation of National Park to Scotland would be acquired in twenty-five years. It might include the Glen Affric, Glen Cannich, Glen Strathfarrar region, with an extention across the Glencarron Road to Loch Coulin and Loch Maree; the region between Invergarry and Loch Hourn; the Cairngorms; some part of the Trossachs, and an area in Central Perthshire, perhaps around Glen Lyon.

In England and Wales, where land is dearer, progress by purchase would be less rapid. On the other hand, however, there are in England large areas of common lands (estimated at 2,500 sq. miles) and of Crown Lands (including the New Forest and the Forest of Dean), much of which would probably be selected for Park purposes, and would entail either a very low purchase price or none at all. Private generosity also might be relied on for substantial aid in extending the area in actual possession and full use. With an annual Government expenditure of about £160,000 on land purchase to supplement the areas derived from these sources, and with all the land that is ultimately desired receiving protection until such time as the Nation is ready to purchase it, there can be no doubt that in England and Wales, as in Scotland, we should, twenty-five years hence, possess or control a system of National Parks of which we need not be ashamed in face of our posterity. And the question is not: whether we can—our resources both in money and in land are ample for the purpose; the question is only: whether we will.

Mr. A. Farquharson.—*Population maps, their preparation and significance.*

Mr. Farquharson exhibited and described a series of maps he had prepared of various districts indicating the distribution and density of population in urban and industrial areas. He described various methods of preparation and dealt at length with the purpose and value of such maps for sociological study.

Prof. Fawcett (Sec. Population Map Committee) speaking in support of the subject indicated that he would welcome the assistance of Corresponding Societies in the preparation of such maps of their respective areas, and invited those societies willing to assist to communicate with him—Prof. C. B. Fawcett, University College, London, W.C. 1—for information and advice.

The Conference considered and supported the following recommendation received from Section E (Geography):—

REVISION OF ORDNANCE SURVEY MAPS.

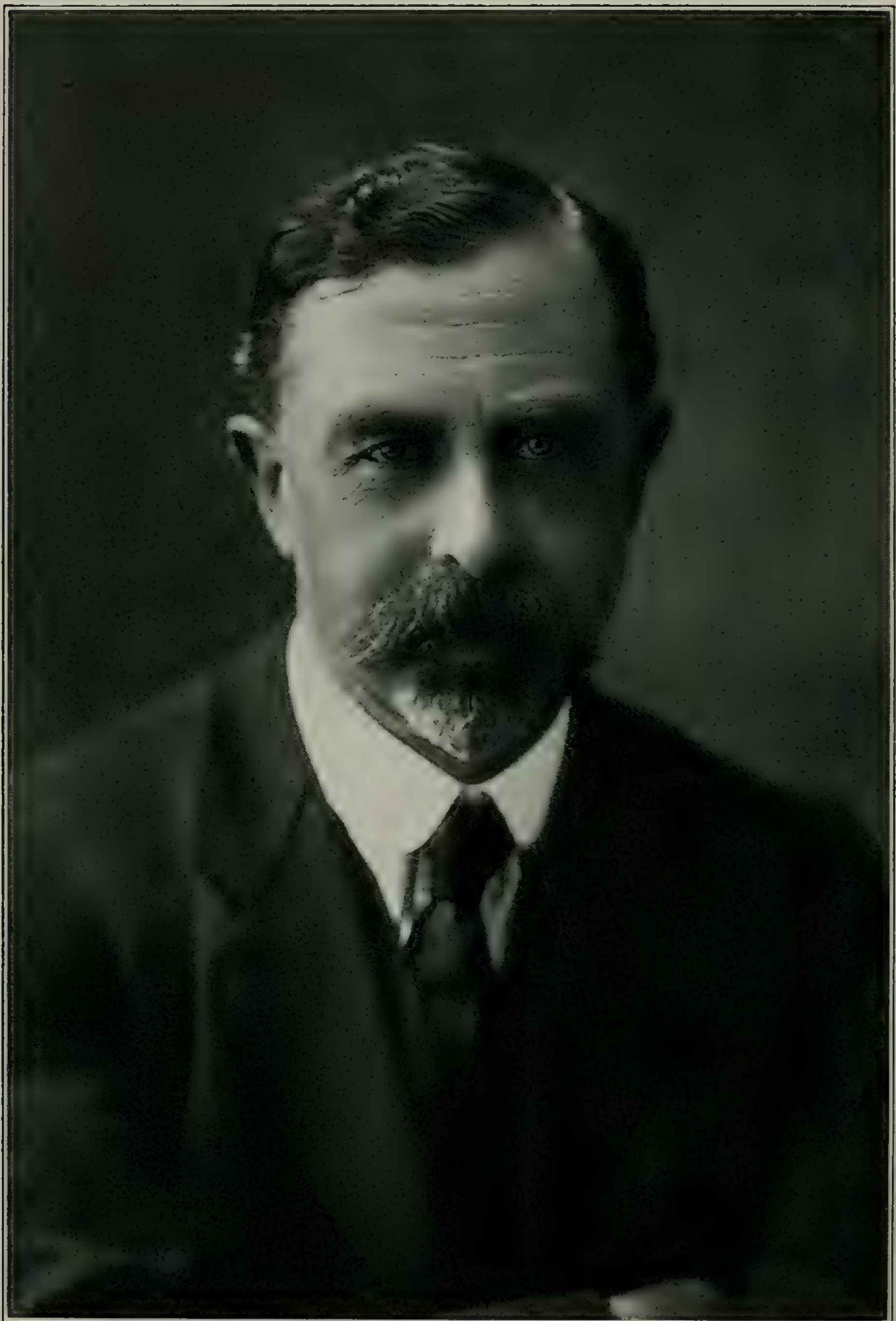
The delay in revision of Ordnance Survey Maps is of long standing, and has been repeatedly brought to the notice of the Association, and by the Association to the Government, but without appreciable result.

The cumulative delay results in needless expenditure of large sums by local authorities and private enterprises in the construction of unofficial maps to replace useless sheets, and has been recently the subject of vigorous comments in the Press. The principal grievance is that the geographical features of large areas formerly rural, are being transformed for various urban purposes. But the Ordnance Survey is under administrative control

of the Board of Agriculture and Fisheries, which is not concerned in urban development nor with the reorganisation of transport to meet urban and industrial conditions.

Recommendation.

The Committee of the Geographical Section therefore invites the Committees of all Sections interested in the provision of accurate modern maps on which to plot the distributions with which they are respectively concerned to support a fresh and vigorous appeal to the Lord President of the Council, and to the Minister of Agriculture and Fisheries, to take such measures as may ensure the provision of ample funds to carry out a far-sighted policy of map revision in the general interest of the community.



Sir William Bate Hardy, F.R.S.

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EVENING DISCOURSES.

FIRST EVENING DISCOURSE

Friday, September 7, 1934.

TRANSPORT AND STORAGE OF FOOD

BY

SIR FRANK SMITH, K.C.B., C.B.E., Sec. R.S.

(Being a Memorial Lecture for Sir William Hardy, F.R.S., late President of the Association).

Introduction.

It is a privilege which I greatly esteem to deliver the Hardy Memorial Lecture, an occasion which for me is fragrant with the memories of him whose life we commemorate; an occasion, too, which is shot with sorrow and regret. Had Providence seen fit, Sir William Hardy would have presided over this meeting of the British Association, and I know he would have addressed you on the subject of research in foodstuffs. It is a subject of which he was the foremost research worker in the world, and he was an incomparable exponent of it. He had command of vivid, robust English which enlivened and adorned all his addresses, and he had a crusading enthusiasm which invested the most intricate scientific problem with a romantic glow which never failed to stir his audience.

To an assembly such as this, it would be superfluous to extol Sir William Hardy's services to science; but I may, perhaps, be permitted to pay a brief tribute to him as a colleague.

William Bate Hardy was of a type which is rare at any time. That he was a born leader all who knew him will acknowledge, and he led, as all true leaders do, by inspiring his colleagues with something of his own enthusiasm, by communicating to them glimpses of his own transcendent vision. He drove himself hard—too hard, alas!—and he could also drive his colleagues; but when he did, he drove them with sympathy and understanding, and such was the affection he inspired, that to expend oneself in the tasks he set was a labour of love. Hardy's greatest characteristic was his zest for life; living was, to him, a thrilling experience; he lived with all his might, and he savoured and appreciated and enjoyed everything that life offered him. I can never think of him without recalling those great figures of our literature that he himself loved so deeply—Chaucer, Shakespeare, Fielding, Dickens. He, like them, was passionately in love with life; he had no fear of it, and he lived with a full-blooded gusto far beyond the range of most men.

He was a great student of social history, and he saw the importance, as few men did, of having more knowledge of the food which we import in such great quantities. He was not concerned with the production of food,

but he knew the history of food production exceedingly well, and he had a great admiration for those scientists and engineers who have succeeded in increasing our food-supplies to such an extent that fear of scarcity has been banished for hundreds of years to come. He often referred to the gloomy prognostications of Malthus, 100 years ago, that the world could not produce enough food to feed its growing population, and to the Presidential Address of Sir William Crookes to this Association when he uttered his famous warning: 'England and all civilised nations stand in deadly peril of not having enough to eat—as mouths multiply, food resources dwindle.' You will remember that Crookes was not concerned with food preservation, but was alarmed at the rapidly diminishing supply of natural fertilisers. To-day, the world is no longer dependent on such fertilisers. Science has shown us how to make them synthetically, and the supply is not only ample but more than ample. Indeed, our manufacturing chemists are seeking new markets and new uses, for the potential supply is greater than the demand. In this country alone, Imperial Chemical Industries can produce two hundred thousand tons of fixed nitrogen per annum, equal to about one million tons of sulphate of ammonia, and no doubt they would like to make more.

The Problem To-day.

Since the days of Sir William Crookes, it is obvious that the problem has changed. The question is no longer 'How can we produce enough food?' but 'Where shall the food be produced, at home or overseas?' If a considerable part is to be grown overseas, and all of it cannot be grown at home, then transport and storage are factors of great importance.

When, seventeen years ago, Sir William Hardy decided to devote the remaining years of his life to the study of foodstuffs, he was attracted by both the scientific and the economic aspects of the problem. In imagination I can see him then looking up the Board of Trade returns, and noting that, even in those days of war, we were importing hundreds of millions of pounds worth of food. Just think of it: about three-quarters of a million pounds of money in this country is spent on an average every day on food brought from overseas. During 1932 imported meat alone was valued at over 78 million pounds; of eggs we imported about two thousand millions, and of apples—if we reckon three to four apples to the pound—we imported about three thousand millions. Of the lamb we imported, seven million pounds worth came from New Zealand, yet seventy years ago no one in this country had tasted lamb from New Zealand. The reason is simple: it could not be transported and remain fit as food. To-day we can eat and enjoy New Zealand lamb, thanks to a great discovery and the engineers who developed the results. I refer to the making of cold by means of heat. We in this country owe much to the refrigerating engineer, who in turn owes his basic knowledge to Rumford, Carnot, Joule, Kelvin and other scientific workers. Hardy, however, was far from content; he was not satisfied merely to know that refrigeration preserved food: he wanted to know exactly what happened to the food when cold was applied to it.

Another problem which was always uppermost in Hardy's mind was that of waste. Of the vast quantity of food which we import and the food which we produce ourselves, how much goes to waste, and how much of this waste might be avoided if only we had more knowledge of the nature of foodstuffs? To Hardy, research on food was not only of vast scientific interest: he was fully conscious that it might lead to economic results of great importance.

Natural Ice as a Preservative.

Cold, which according to modern knowledge is the best of all preservatives, does not appear to have been used in ancient times, although snow and ice were used in cellars for cooling wine. Perhaps the earliest recorded experiment in the use of cold as a preservative is that of Francis Bacon who, in 1626, stuffed a fowl with snow and found the method answered ' excellently well.' He died a few days later, but his death does not appear to have been in any way connected with the stuffed fowl.

The use of cold as a preservative no doubt arose by man observing that in cold climates such foods as meat lasted longer than in warmer ones, and the delay in its development was probably due to the difficulties of transporting natural ice. With the improved means of transport available at the commencement of the nineteenth century, we find Wenham Lake ice being imported from America, and when, later, the trade was transferred to Norway, Lake Oppergard was renamed Lake Wenham to preserve the trade name. Sir William Hardy, who loved the sea and everything connected with it, was fond of telling how he remembered lake ice being brought to this country in sailing vessels, and how he watched the ships discharge ice alongside a type of smack long since vanished, which brought cod back alive in a ' well,' the ship's ' well ' being open to the sea by holes bored in the ship's bottom.

Meat arrives from Australia.

The success of cold as a preservative, limited though it was in application owing to the relatively small supply of natural ice in summer-time, and ignorant though we were of the cause of preservation, led to a bold experiment being made in 1860. It must be remembered that during the previous half-century the rapid expansion of the population of this country was creating a good deal of anxiety for our food-supplies, especially meat, and had given rise to a trade with North America, and later with South America, in live cattle. It was obvious that the transport of live cattle over long distances was not a convenient solution of the problem, and Australia and New Zealand, with an ever-increasing surplus of sheep, were too far away for transport of these animals to be undertaken with ease and profit. So it was that in 1860 an experimental cargo of meat was shipped by James Harrison from Australia with natural ice to keep it cold, but, as many expected, the ice failed to last the voyage, and the meat had to be jettisoned. But the experiment attracted much attention, and it is not surprising to learn that a few years later natural ice was successfully used for shipping meat on the much shorter voyage from North America.

Engineer's Ice.

The failure of James Harrison stimulated engineers to build refrigerating machinery for ships, and in 1877 the first cargo of meat to be shipped and preserved by ' engineer's ice ' was landed from Australia by the steamer *Strathleven*, a Bell-Coleman refrigerating machine being employed.

Five years later—that is, in 1882—the sailing ship *Dunedin* of the Shaw, Savill and Albion Line, fitted with a machine of the same make, made the voyage from Port Chalmers, New Zealand, to London in 98 days, and landed five thousand carcasses of frozen mutton which fetched 6*d*. per lb. Thus it was that the transport of meat from Australia and New Zealand began, and the beginning of the story is but fifty-seven years ago. In 1865

our imports of fresh or slightly salted meat were 45,000 cwt.; in 1932 over 30 million cwt. were imported, thanks largely to refrigeration.

To-day practically all the cold used for preserving food is artificially produced, and the achievement of the refrigerating engineer during the past fifty years can only be described as prodigious. Here are a few facts to illustrate the advances which have been made. Whereas sixty years ago there was no refrigerating machine and no cold storage provided in ships, to-day the refrigerated space used in bringing foodstuffs overseas to this country alone amounts to not less than 100 million cubic feet, equivalent to a floating cold store 20 ft. high, 50 ft. wide and 20 miles long. The capacity of the public cold stores in Great Britain amounts to about half of this, while our annual output of artificial ice is one and a quarter million tons, of which the fishing industry uses three-quarters of a million tons.

Refrigerated Imports.

What do these ships and stores and ice do for us? Here, in round figures, are some of the main items which the ships brought us in 1932:

Meat	1,500,000 tons
Fruit	500,000 ,,
Butter and cheese	500,000 ,,
Eggs in shell	480 millions
Fish	69,000 tons

So much for quantity, impressive enough in itself, but not, perhaps, so impressive as the way in which mechanical refrigeration has enabled this country to obtain its food from the four corners of the earth. Not fewer than thirty countries contribute to our food-supply by the help of refrigeration, and it may truly be said that the food which we eat is now practically independent of the seasons. Apples are now obtainable in excellent condition, and at prices within the means of the bulk of the population, the whole year round. North America supplements our home-grown crop and carries us through till April, when Australia and New Zealand take up the task and supply us till our own season comes round again. South Africa refreshes us with her oranges and grape-fruits throughout the summer, and at Christmas graces our tables with her peaches, pears, nectarines and plums.

Before artificial refrigeration came, the population was obliged to depend for its food, other than relatively imperishable products, such as cereals, upon an area within a radius of a few hours' journey. As the density of the population increased, these areas became less and less able to furnish the necessary supplies, and had such conditions persisted, the dietary of the population must have suffered severely. As it is, refrigeration has had the effect of rendering dense populations less and less dependent upon adjacent agricultural areas for their food. But for refrigeration, the density of the population found in Great Britain could hardly have been possible.

Such was the kind of knowledge that was available to Hardy when he commenced his work in 1917. The rise and achievements of the refrigerating engineer were apparent to him, and he realised all that they meant politically and socially. He was fond of pointing to a coster's barrow piled with fruit in winter-time, and summing up the situation in such words as 'Science and the Engineer. Fruit for the poorest all the year round!'

But, as I have already stated, a survey from the outside did not satisfy Hardy. He deemed it essential to find out why refrigeration preserved food; this was not possible without more knowledge of the nature of food

itself. He found, as he expected, that the development of food preservation had been lop-sided—a lop-sidedness which reflected to some extent the difference in the rates of development of the physical and biological sciences. On the physical side the science of refrigeration had grown at a rapid rate, but on the biological side the advance had been slow. Hardy once remarked that the position was as if we were aware of the functioning of an internal combustion engine without any knowledge of internal actions and with little knowledge of its moving parts. How could we hope to make such an engine function more efficiently without some knowledge of how it worked ?

Clearly it was essential to know more of the biological side of food. The proper order of things was for the biologist to formulate the conditions required for the satisfactory storage of the varied biological material which forms our food-supply, and for the engineer to provide the conditions. And so in recent years there has been a large expansion in biological research on foodstuffs, and to-day the biologist is beginning to frame the specifications which the engineer must attempt to realise in practice. On the methods of storage of the three types of perishable food, meat, fish and fruit, the work of Hardy has had considerable effect. I propose to consider the dead foodstuffs, viz. meat and fish, first, since in some respects their storage presents a simpler problem.

Meat.

Autolysis.—Take meat. It is dead. The problem is to prevent any undesirable changes. If there are agencies promoting changes, they must be resisted or slowed down to a point beyond which their effect becomes negligible. In meat, changes of two types have been discovered. First, there are the changes brought about by the enzymes naturally present in the tissues—in other words, by autolysis. Experiments show that such changes are dependent on the temperature. At the freezing-point of water the changes are slowed down so that they are negligible for a period of six months, while at $-10°$ C. they appear to be completely inhibited. Cold, therefore, may be employed to control changes due to the enzymes.

Micro-organisms.—The second type of change in meat is due, not to anything inherent in the meat, but to micro-organisms, chiefly moulds and bacteria. With the occurrence of death animal tissues become a rich medium for the growth of micro-organisms. The changes in the meat produced by these organisms are not only unsightly, but there is alteration of the colour of both lean and fat, and tainting results through the production of substances of unpleasant odour and taste which diffuse into the flesh. The problem is to prevent or reduce the magnitude of these changes. Examination of the flesh of animals shows it to be normally sterile, and if perfect asepsis could be maintained in the slaughter-house, the store and shop, micro-organisms would not be a cause of deterioration.

The rate of change due to micro-organic contamination has been measured, and meat is found to be unsaleable when the bacterial population reaches a density of 30 million organisms per square centimetre. The time interval needed to reach this critical density depends, as would be expected, on the initial contamination. For instance, at a temperature of $0°$ C. and 100 per cent. humidity, the critical density is attained in 7 days on the cut surface of lean meat if the initial bacterial load is 100,000 per square centimetre. If, however, the initial load is only 10 per square centimetre, the critical density is not reached for 18 days—in other words, the ' edible life ' of the meat is more than doubled. Clearly it is of extreme importance to

reduce this bacterial contamination to a minimum, and while perfect asepsis is impossible, every possible precaution should be taken to keep the contamination at a low level.

There should, indeed, be prominently displayed, in all places where foodstuffs are handled, Florence Nightingale's maxim, 'Cleanliness is the only real disinfectant.'

Effect of Cold.—Fortunately, experiments show that the growth of these micro-organisms can be controlled by cold, the growth ceasing altogether at a temperature of -7° C. Storage for very long periods is therefore possible. However, from slaughter-house to consumer meat cannot be kept continuously at -7° C., and the necessity for scrupulous cleanliness in the handling of foodstuffs is still essential: nothing else can make so great a contribution to success in their storage and transport.

It thus appears that refrigeration forms the fundamental means whereby meat may be successfully stored and transported. The freezing-point of meat is approximately -1° C., and if autolysis and the growth of micro-organisms were the only considerations involved, freezing at a temperature below about -10° C. would be an ideal method of preservation. At this temperature fresh meat will remain wholesome for a year or more, but bacon deteriorates more rapidly through oxidative changes in the fat.

The problem of storing meat appears then to be solved, the application of cold at -10° C. being the solution. Unfortunately, however, freezing itself produces changes which damage the meat to some extent, and though the damage may only be in appearance and is negligible in mutton, lamb and pork, it is considered by the trade to render freezing, as distinct from chilling, an unsatisfactory process for beef.

Drip.—Let us consider what happens to meat when it is frozen. One effect of freezing is similar to that of drying; both remove water, but whereas in drying the water is entirely removed, in freezing it remains in the tissue in the form of ice, and is thus free to be reabsorbed when the tissues are thawed. The proportion of water frozen out of the tissues depends on the temperature. In the case of muscle it is about 17 per cent. at a temperature of -1° C., and about 98 per cent. at a temperature of -20° C. The ice is in the form of crystals, and the size of the crystals depends, not on the temperature alone, but more particularly on the rate of freezing. When meat is frozen slowly, the bulk of the ice is formed between the muscle-fibres and the crystals are large; such crystals have a disruptive effect upon the fibres, and the result is that when the meat is thawed the water is not entirely reabsorbed but partly drains away, carrying with it dissolved protein, salts and pigments. This is unsatisfactory. But as the rate of freezing is increased, less and less ice is formed between the muscle-fibres and more and more within them, and the size of the ice crystals is also diminished. The result is that when meat is frozen at a rapid rate, since there is more moisture reabsorbed on thawing, the 'drip,' as it is called, is less when the meat is thawed. It should therefore be possible, by increasing the rate of freezing, to form the whole of the ice within the muscle-fibres and none between them, and in such case there would be no 'drip' at all on thawing. This reasoning is perfectly sound, but the requisite rate of freezing is so high that it is unattainable in pieces of meat thicker than about $2\frac{1}{2}$ in., and quick freezing is therefore applicable only to small cuts, such as chops and steaks. Moreover, not only must the rate of freezing be high, but the temperature of storage must also be maintained at a far lower, and therefore more expensive, level than is usual, for it is a well-known physical fact that, even when small ice crystals are formed, they tend to grow at the expense of their fellows, and the rate at which they grow increases with the

temperature. It has been found that if the advantages of quick freezing are to be retained, the meat must be stored at a temperature not higher than $-20°$ C.

Chilling.—The fact that freezing is an unsatisfactory process for beef has led to alternative methods of storage being explored. As is well known, much of our beef comes from foreign countries, and it may be asked how it is that it is brought here so successfully. As the ideal method appears to be storage at a temperature not higher than about $-10°$ C., the question arises, 'Is imported beef stored at this low temperature?' The answer is that the bulk of such meat is not frozen: it is only chilled—i.e. the meat is cooled only to temperatures at which little or no ice is formed in it. The temperature employed is about $-1°$ C. At this level, as already stated, the growth of micro-organisms, while retarded, is not arrested, and I have already pointed out that, were the bacterial contamination initially high, the meat would become unfit for food after a week or so. At this point I would like to pay tribute to the importers of chilled beef to Great Britain, for the normal life of such beef is five weeks or more, a success which is largely due to the admirable control that has been established over the conditions from the slaughter-house in South America through the whole chain of transport to the retail butcher here. In other words, the detrimental effect of micro-organisms has been fully realised, and the greatest care is taken to keep such contamination at the minimum.

It is clear that, even if the greatest precautions were taken, since the normal life of chilled beef at $-1°$ C. is only about five weeks, export of chilled beef from Australia and New Zealand is not, or rather was not, a feasible proposition. This fact, and the desirability of increasing the life of chilled beef, led to researches being made with a view to finding other means than low temperature of controlling the growth of micro-organisms. To some extent the growth can be controlled by regulating the humidity of the ship's hold, for the lower the humidity the slower the rate of growth. If, however, the humidity is very low, the loss of weight by evaporation from the meat is considerable, and there is thus a strict economic limit to the extent to which the humidity can be lowered. How much this question of loss of weight means will be gathered from the statement that if the present loss of weight in New Zealand mutton and lamb could be reduced by one-quarter, it would be worth £100,000 a year to the industry. It was desirable therefore to look in other directions than controlled humidity, and within the last few years research has discovered still another means of controlling bacterial growth.

Gas-storage.—It so happens that the most important micro-organisms attacking meat, both bacteria and moulds, are specially susceptible to carbon dioxide, and that, at temperatures in the region of the freezing-point, a concentration of 10 to 20 per cent. of this gas so delays their growth as to double the life of the beef. While the mode of action of carbon dioxide is not yet clear, it may be due to the consequent change produced in the hydrogen-ion concentration—i.e. in the acidity of the meat. On the other hand, there is some evidence that the carbon dioxide acts directly on the micro-organisms by depressing their respiratory activity. Further research will clear up these points. It will no doubt be asked why the concentration of carbon dioxide should not be still further increased, so as to retard even more, or possibly to inhibit, the growth of micro-organisms. Unfortunately, however, at higher concentrations the carbon dioxide has adverse effects in other directions, which I will now describe.

Bloom.—Most people know what is meant when meat is said to have a good 'bloom': it constitutes that bright, attractive appearance of freshly killed

meat. 'Bloom,' like beauty, is but skin deep, but it is not less highly valued. Loss of 'bloom,' though without any nutritive significance, may, for instance, reduce the wholesale price of frozen lamb by as much as $\frac{1}{2}d.$ per lb. 'Bloom' is found to depend on two things: first, an adequate supply of the red pigment of blood and muscle, hæmoglobin, and secondly, the translucency of the layer of superficial connective tissue and fat through which this pigment is seen. 'Bloom' will therefore be impaired if either of these two conditions is below standard. Let us first consider the layer of connective tissue and fat. If its normal translucency is to be retained, absorption of water must be avoided, and so must excessive drying. In storage, absorption of water may readily take place when the cold carcass is exposed to a warm, humid atmosphere from which moisture may be deposited on it. Turning to the second factor, the red pigment, hæmoglobin, the intensity of the colour depends both on the concentration of the pigment and on the depth of the layer of muscle from which the light is reflected. Up to a certain point drying increases the colour by increasing both the concentration of the pigment and the translucency of the tissue, but if drying is allowed to persist beyond a certain point, it results in the formation of minute air-pockets, which, like a lot of minute air-globules in a piece of glass, scatter the light falling upon them and decrease the depth of the reflecting layer. At times this takes place to such an extent that the muscle appears a greyish yellow colour instead of red. Further, when the meat is exposed to air, oxidation takes place and changes the red hæmoglobin into the dirty brown methæmoglobin, but the rate at which the oxidation takes place depends on the pressure of oxygen, being greatest in comparatively low pressures. Moreover, decrease in the hydrogen-ion concentration also increases the rate at which methæmoglobin is formed. Now, if carbon dioxide is added to the air of a beef store, both the hydrogen-ion concentration and the pressure of oxygen will be lower in the stored meat than if it was stored in air alone. High concentrations of carbon dioxide therefore produce rapid discoloration, but, fortunately, for concentrations up to 20 per cent. the increase in the rate of formation of methæmoglobin is negligible. It is clear, however, that such high concentrations of carbon dioxide as to inhibit completely the growth of micro-organisms are not admissible.

Application.—What about application? The story I have told you of carbon dioxide results in the main from experiments carried out in the laboratories of the Low Temperature Research Station at Cambridge under Sir William Hardy's direction. It appears clear that beef, with the aid of refrigeration plus the aid of carbon dioxide, can be maintained in first-rate condition, although only chilled, sufficiently long to carry it for 13,000 miles—that is, from one side of the world to the other. And to-day this is being done. The laboratory experiments have been fully verified by large-scale experiments at sea, and the historic shipments of meat under refrigeration in the nineteenth century had their counterpart last year when a shipment of beef was made from New Zealand in the *Port Fairy* of the Commonwealth and Dominion Line. It was the first consignment of chilled beef to be carried overseas in gas-storage. It was strikingly successful, and similar shipments of chilled beef, though at present small, are now regularly made from Australia and New Zealand, while arrangements for the rapid development of the trade are being made by the great meat interests and the shipping companies. In the journal 'Food' for July last a description is given of the twin-screw motor ship *Port Chalmers*, owned by the Commonwealth and Dominion Line, the first vessel to be specially built with gas-tight compartments suitable for the gas-storage of chilled beef. This vessel left

London on her maiden voyage to New Zealand last January. Carbon dioxide for the chilled beef is carried in 160 steel bottles.

Fish.

Let me now turn to that other great section of our animal food, fish. Fish is of special interest to Aberdeen, not only because Aberdeen is a great fishing port, but also because it was chosen by Hardy as the site of the Torry Research Station, the only institution in Great Britain that is devoted to research on the storage and transport of fish. A modest institution maybe, but the value of research does not depend on bricks and mortar.

Many here will no doubt have read the recent report of the Sea-Fish Commission on the Herring Industry. At the outset that report states that 'the article [that is, the herring] is highly perishable, making short voyages and immediate landing at the ports imperative,' and in a footnote appears the statement: 'Herring caught more than 24 hours before landing are known in the trade as "overdays," and are of inferior quality.'

Obviously in the problem of storage of fish, with the knowledge that a herring twenty-four hours old is an 'overday' of inferior quality, Hardy had a subject after his own heart, for he loved a difficult task, and he loved it even more if it were associated with the sea.

Fish, as food, is like meat: it is dead, and it was not surprising to find that the two main causes of deterioration in fish are the same as those operating in the case of meat, namely, autolysis and the action of micro-organisms. Of these causes the second is by far the more important, the predominant organisms being bacteria.

Smoking and Drying.—As is well known, one of the earliest methods of preserving fish is that of smoking, which has been developed by the fishing industry itself on the basis of long experience. Fish are still smoked to-day as in olden times, over smouldering fires of sawdust, and it is not surprising that the scientific man, accustomed to controls in most of his work, looks at the process and wonders why it has never been put on a scientific basis. The final condition of the fish must depend not only on the antiseptic substances in the smoke, but on the range of temperature, the percentage humidity of the drying atmosphere, and on the rate of change of temperature and of humidity. At first there appears to be an absolute want of control of any of these factors, and, in fact, there are no mechanical controls such as we are accustomed to in modern industrial processes; the one control is the human one, the smoker himself, who alters the position of the fish relative to the fires, adjusts the damping, and makes other small changes. The process in some measure must be at the mercy of the weather, and control of the cure is limited to the extent to which craftsmanship—and all of us admire the craftsmanship of both fisherman and curer—can overcome the inefficiency of the plant. In this process of drying and smoking, water is withdrawn and the action of the enzymes, that is, autolysis, is very much slowed down. The smoke, in addition to being a method of drying, also acts as a preservative by virtue of the antiseptic substances, such as formaldehydes and cresols, which it contains.

Here, clearly, is a wide and interesting field for research if the process is to be brought completely under control. The problem was tackled here in Aberdeen at the Torry Research Station, and I am glad to say that substantial progress has been made: in fact, it is not going too far to say that the framework of a method giving adequate control has been erected. In the experimental work the variables were isolated as much as possible. The experiments on temperature showed that a rise from 70° F. to 90° F.

over a period of 3 hours produces a good, pale colour with haddocks. If the deeper colour of the Finnan cure is required, the temperature should be maintained at about 80° F. for a further 2 hours. During the process the fish naturally loses water, and it is clear that the final result must depend on the rate at which the water is lost—i.e. it will depend on the humidity and the rate of displacement of the air. Experiments have shown that increase in the velocity of the air beyond 10 ft. a second has little effect, but up to that speed the loss of water by the fish increases with the air-speed, provided, of course, that the air is not already saturated with moisture. That brings me to the third variable, humidity. The important point here is the capacity of the air to take up water. In practice it is found that, for a rise in temperature from 70° to 90° F., a relative humidity of about 50 per cent. gives the best results, producing a satisfactory cure, and at the same time keeping the loss of weight down to the minimum, namely, about 25 per cent. for the fully cured fish.

Knowing the best conditions, controls of temperature, humidity and movement of the air are very easy problems for the physicist, and the summed result is complete control of the drying of the fish. Control of the smoke, which is responsible for the antiseptic substances, has been achieved by separating the two processes of drying and smoking. The drying kiln is heated by controllable methods such as gas-burners or electrical heaters, and the smoke is made in a box external to the kiln. Burning sawdust is used, and the rate of burning is governed by a small electric blower, the smoke being piped to the kiln through a conditioning tank in which its temperature is lowered to about 60° F. At this temperature the smoke is fully saturated with moisture, but as the kiln is at a higher temperature, the percentage humidity drops to the required degree on entering the kiln. To produce the even smoking of the fish, the experimental kiln at Torry was fitted with fans to ensure even circulation of the smoke, first in one direction and then in the opposite. With such an experimental plant it was a simple matter to produce any desired cure with certainty; no matter what the external atmospheric conditions might be, it was easy to secure the evenness of cure, brilliance of colour, cleanliness, and excellence of flavour on which the quality of the finished product depends. Moreover, 'droppers' were avoided, 'droppers' being the softened fish which fall off the hooks.

It may be thought that the expense of such a plant would render it uncommercial, but I believe this is not the case. The improvement and consistency in the product, and economies in other ways, are considerable, and I am glad to say that commercial kilns are being developed with success on these lines.

Salting.—Another old process of preservation is salting, and it is of special importance to the herring fishing industry, for about one-half of the catch is treated by this process.

The common salting process is the 'hard' cure in which the finished product contains about 15 per cent. by weight of salt, as against 0·2–0·3 per cent. in the fresh fish. It is essential to keep the concentration of salt high if the fish is to be kept in good condition for a reasonable period of time at normal temperatures. Unfortunately, the export trade in the 'hard'-cured fish has seriously diminished, and at home the 'hard'-cured fish makes no strong appeal to the consumer's palate, being both too salt and too desiccated. In 1932, the last year for which figures are available, the export trade was only some 4 million hundredweights, as against over 6½ millions in 1913. With these facts in mind, research has been carried out with the object of relating palatability and keeping quality with

the amount of salt used, and of determining to what extent the preservative action of salt might be reinforced by cold storage. This work is only in the preliminary stages, but already it is clear that fish with the authentic rich, cured flavour can be produced with a much smaller concentration of salt in it, viz. 5 per cent., a level at which only some 10 per cent. of the water has been extracted. Moreover, when the herring are cooked without previous steeping, they are almost as soft as fresh herring. It was found that, with this smaller percentage of salt, herring would not keep more than a few days at normal temperatures, but if chilled at 0° C. they remain fresh for about a fortnight, and are fresh for three months or more if stored at −6° C. What the commercial possibilities along these lines may be I do not know, but the idea of combining salting and chilling, as the meat trade is combining chilling and gas-storage, certainly seems worth exploration, and might do much to assist in restoring the salt-cured herring to favour in the home market.

Chilling.—Obviously, if there is a method of preserving fish which adds nothing to it, extracts nothing from it, and does not alter its properties, such a method should be the most satisfactory. In other words, if chilling or freezing alone can be made to give satisfactory results, such methods are probably best. Before dealing with this aspect of the subject, I propose to describe very briefly what has happened in the sea-fishing industry during the last century.

Until about 100 years ago, sea fishing was confined to a number of comparatively small local centres, for the absence of any artificial means of preservation, coupled with the slowness of transport, strictly limited the supply of fish to inland markets. Then came a rapid development. The railways made speedy transport possible. The steam trawler, and steam for hauling gear, increased the power of the fishing fleet, and the use of artificial ice for storage added four or five days to the ' life ' of the catch. The fresh fish supplied to the inland markets was consequently much more palatable than before, and inland markets rapidly developed. They developed, in fact, to such an extent that home waters became unable to cope with the demands, except in the case of herrings. Consequently, larger fishing vessels were built, having a much greater range than the previous ones, and the fishing-grounds of the Faroes, Iceland and the Eastern Atlantic were exploited. White fish, such as cod, haddock and plaice, became the main catch, and steam trawling became the chief method of catching. The development has been such that at the present time there are about 1,600 steam trawlers fishing from our ports, and last year they landed nearly seven hundred thousand tons of white fish, having a value of some 12½ million pounds.

Such was the situation in 1929 when, with Hardy at the helm, the Torry Research Station was established. There was, on the one hand, a good market for really fresh fish, and, on the other hand, far too large a proportion of stale fish was being landed. It was clear to Hardy that, as practised, stowage in crushed ice, in other words, the chilling of fish, good though it was, was not fulfilling all requirements. The principles discovered in the experiments on meat pointed to a possible solution of the problem. Research showed that stowage in crushed ice adequately delays autolysis, but it does not lower the temperature sufficiently to cope with the bacterial growth. Consequently, as with meat, if stowage at chilled temperatures was to be brought to its full effectiveness, every possible step must be taken to minimise bacterial contamination during gutting, stowing, and all subsequent handling of the fish. While Hardy realised that nothing approaching complete asepsis is possible under the conditions of commercial

fishing, he pointed out that much can be done, and in certain directions is now being done, to improve matters. The effort is well worth while. Stowage in crushed ice under ordinary commercial conditions keeps fish fresh for not more than six or seven days, but if reasonable steps are taken to reduce the bacterial contamination, this period can be extended to ten or twelve days: in other words, the edible life can be practically doubled. It is concluded that twelve days may be taken as the limit to the 'life' of clean, chilled fish.

Freezing.—Now, in a comparatively small country like ours, the interval between the landing of fish and its consumption is not usually very great, and the question arises, For what proportion of the trawling industry will a twelve days' limit suffice? It will certainly suffice for the fish which is landed from trawlers making trips not exceeding fourteen days, and these account for about two-thirds of the total landings of white fish.

But about one-third of the fish landed is from trawlers making trips of over fourteen days' duration. A typical voyage is to the fishing grounds off Iceland, taking say twenty-four days, of which fourteen will be occupied in steaming to and from the fishing grounds. In such a case the earliest caught fish landed by such vessels will be some seventeen days old on landing, and the latest caught fish will be some seven days old. It is clear, therefore, that the mere chilling of clean fish is not sufficient for these long-distance trawlers. More effective methods than stowage in crushed ice are necessary.

As with meat, freezing offers a possible solution. Early experiments showed, however, that the ordinary freezing of fish in cold air did not yield a satisfactory product. The appearance of the fish was bad, and there was a considerable amount of 'drip'; moreover, the fish was dry, and when cooked it was woolly and tasteless. It was clear that the rate of freezing, which we saw was so important in the case of meat, was too slow. Attention was therefore turned to more rapid freezing in cold brine. At first even the results of this brine-freezing were disappointing, but research was able to track down the cause, and eventually a product, practically indistinguishable from freshly caught fish, was obtained by freezing in brine at a temperature not higher than $-20°$ C. It is not until this low temperature is reached—a temperature, incidentally, at which the growth of bacteria is completely arrested—that a sufficiently rapid rate of freezing results. To preserve the high quality, the minute ice crystals formed must not be allowed to grow too large and disintegrate the fish, and this necessitates storing the frozen product at the same low temperature. If that be done, fish can be stored for three months, and on thawing it has been found as good to look at and to eat as if it had just come out of the sea. After three months some change has been found in the laboratory, but the rate of change is so slow that it has no commercial significance for at least another three months, and it is now certain that fish can be stored in first-rate condition for at least six months.

In practice, the catch should be frozen at sea as soon as possible after it comes over the side. I fully realise that the cost of installing the necessary plant and operating it is substantial, but I do seriously suggest that this extra cost would be more than met by the saving in depreciation of fish at present stowed in ice for periods over which we know full well that ice is powerless to prevent the fish from becoming stale. For the present, it is not essential that the long-distance trawler should carry a larger plant than is required to deal with one-third of its catch.

It is exceedingly satisfactory to me, in drawing these remarks on fish to a conclusion, to refer to the boldest and most remarkable developments the sea-fishing industry has ever witnessed. I refer to the enterprise which

has fitted a ten-thousand-ton vessel, the *Arctic Queen*, owned by Messrs. Hellyer Bros. of Hull, as a floating factory for dealing with that valuable fish, the halibut. Brine-freezing is the basis of the enterprise. This great vessel is fitted with plant for brine-freezing, and can store at $-20°$ C. no less than four thousand tons of halibut at the rate of seventy tons a day. In May she goes as far afield as the Davis Straits, off the coast of Greenland, where the fish are caught, and at the end of the season, in October, she returns to Hull, and there acts as a floating cold store, discharging her fish according to the needs of the market. If such a factory ship could transfer her fish to cold stores ashore on her return to this country at the end of the Greenland season, there are possibilities, which cannot be ignored, of her fishing throughout the winter in warmer waters. Up to the present, however, there has been no suitable cold storage available ashore, but two stores, able to maintain a temperature of $-20°$ C., have just been constructed at Grimsby and Fleetwood.

In addition to her main task of brine-freezing and storing halibut, the *Arctic Queen* freezes and salts a certain amount of cod, manufactures cod-liver oil, and freezes and stores the halibut livers, which yield oil far richer medicinally than that of the cod, but which demand a different process of extraction, and one not so suitable for operation at sea. She is, therefore, truly a floating factory. It is worthy of remark that there are now several other factory ships at work on like principles.

Fruit.

I now pass to fruit, leaving the world of the dead for that of the living. Fruit is alive, and must be preserved alive. It cannot be frozen, because freezing kills it.

When Hardy and those associated with him commenced their research on fruit, they started in the belief that an intensive study of one fruit would reveal facts applicable to all, and the fruit chosen for the first experiments was the apple. They realised afterwards that they were far too optimistic, for even one type of fruit like the apple reveals idiosyncrasies to the point of absurdity. Nevertheless, a concentrated study of a single fruit like the apple was undoubtedly wise, and this evening I propose to deal with the apple only.

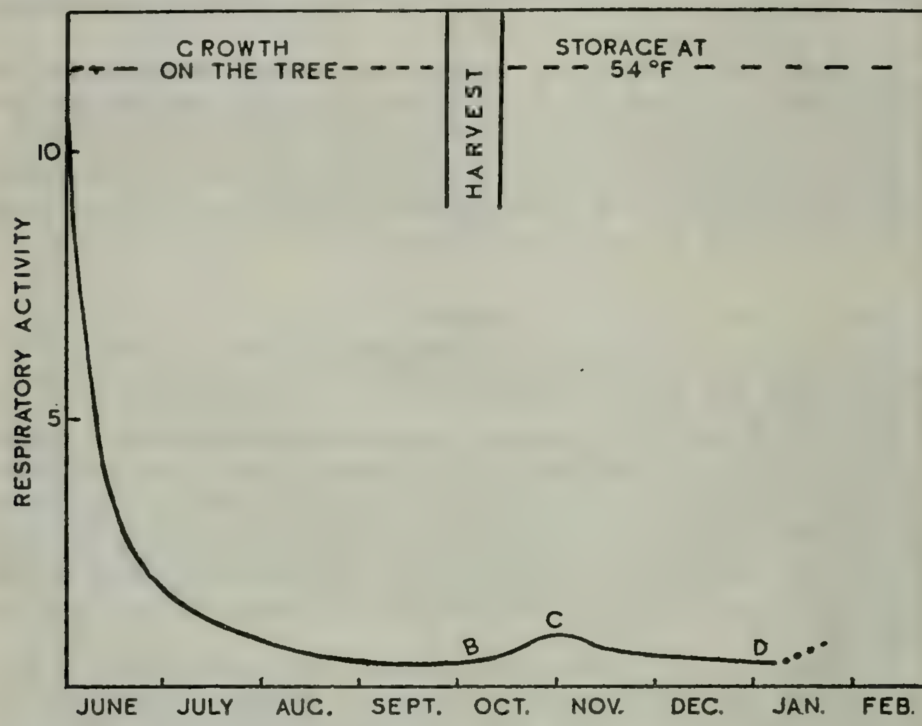
I suppose that we eat more apples than any other kind of fruit. In 1932 we imported over 8 million hundredweights of apples, of which Australia and New Zealand sent us over 2 million hundredweights, and Canada over $1\frac{1}{2}$ millions. Exactly how many apples are grown in this country I do not know, but if we assume that we grow an amount equal to that imported we consume about 6,000 million apples every year if we take three to four apples to the pound.

Of oranges we imported over 9 million hundredweights in 1932, and of bananas over 17 million bunches. While these latter fruits have been studied to some extent and researches are being continued, we have much more scientific knowledge of the apple. Moreover, the story of the apple is Hardy's own story, and it is so full of interest, and the results of the investigation are so far-reaching, that a Memorial Lecture to Hardy would be incomplete without it.

The Life of the Apple.—As with man, there are many ages in the life of the apple, and like man the apple breathes in oxygen and exhales carbon dioxide and water. It breathes out other substances in minute quantities, but the principal products of the apple's combustion system are carbon dioxide and water.

Clearly, it was desirable to get as much information as possible about the rate of respiration of the apple, and so experiments were made in which apples were enclosed in small chambers through which air was passed in a steady stream in order that the rate of breathing of the apples could be measured. The purity of the air was known, and the quantity of carbon dioxide given off by the apples was measured in the ordinary way. The results are given in the diagram. The curve starts in May when the apple sets ; from May to September inclusive, the normal apple lives on the tree, and as it grows it becomes less acid and changes its colour, while its seeds come nearer to maturity.

It will be observed that in the early stages respiration is rapid, but the rate falls until, as maturity is approached, it is but one-tenth of the starting



value. Then, corresponding to the point B on the curve, there comes a sudden critical change in the life of the apple—a change which is called the climacteric. The rate of respiration is rapidly doubled, flavour and aroma are developed, and the apple attains maturity at C. Thereafter the rate of respiration slowly subsides until the fruit dies, death itself being marked by a short-lived rise preceding the final collapse. Instead of there being seven ages as in man, in the life of the apple there appear to be four ages.

Under natural conditions the history of the apple would end at B, and at this point a wild apple would fall, the function of the apple as an organ of the tree being merely to provide the seeds with cover whilst they are ripening. From B onwards the store-keeper, the salesman and the consumer are keenly interested in the apple. In the curve the period B–D is about three months ; the problem is to prolong it to six months or more.

You will not be surprised to hear that the research worker found the apple, like most living matter, to react in an extremely complex way to any

attempt to control its life-history. English apples want to go their own way, live normally for a few months and no more. When the process of ripening is retarded by cooling or in some other way, the chemical changes are apt not only to be slowed down, but to depart somewhat from the normal; abnormal products may then be formed, which, among other things, alter the flavour of the apple. Now, no one would wish to purchase a long-stored English Cox's Orange Pippin, which possessed the flavour of a very inferior variety, on the score that the apple was good. Clearly, it is not sufficient merely to keep an apple so that it is good as food; the storage must be such that the product is both palatable and as near as possible in all its properties to those of fresh, unstored fruit.

Since the changes which take place in the apple are, broadly speaking, chemical changes, the fact that cold prolongs the life of an apple is not surprising, for most chemical changes go on more slowly the lower the temperature. Let us consider the question of temperature first.

Effect of Temperature.—It has long been known that the life of apples is prolonged by storage in cold rooms with appropriate ventilation, and naturally the first researches aimed at obtaining data connecting the life of the apple with the temperature of the air in which the apple lived.

Roughly speaking, an average apple respires about five times as fast at a temperature of 70° F. as it does at 35° F. The explanation of the preservative effect of cold is apparent; the lower the temperature, the less does the apple lose its substance, and the longer is its probable life. I have already mentioned that the apple must not be frozen or it is killed; provided, however, that the apple is not killed, it appears that the lower the temperature the longer is the life of the fruit.

But there are other factors. Apples vary in their tolerance of cold. It is well known that for about nine months of the year our table apples are from overseas, yet some of these are gathered at the same time as our own. The difference is that many of the overseas apples can be successfully stored in cold chambers for much longer periods than English apples: for instance, English apples do not do so well in cold storage as those from N.W. America, where the climatic conditions, higher temperature, lower humidity, and abundant sunshine appear to confer greater tolerance. But apart from differences of this kind, due to large differences in the conditions of the growth of the fruit, varieties in the same country, even in a small country like ours, differ very much in their tolerance of cold. For instance, reducing the temperature from 37° to 34° F. may lengthen the storage life of one variety of apple by, say, 25 per cent., but it may actually shorten that of another variety by the same amount. In the latter case life is ended, not as it normally is, by fungal rotting, but by physiological disorder directly caused by the cold and known as 'low-temperature breakdown.'

Let me refer to the figure again. The two parts BC and CD are two stages in the life of the apple, and the reaction of the apple during the BC part of its life is different from that of the CD portion. In the case of Bramley's Seedlings, the fruit is peculiarly susceptible to internal breakdown when subjected to cold during the BC portion of its life, but for the CD portion it is only slightly susceptible to internal breakdown, but increasingly liable to attack by fungi. These two types of disease are of very considerable commercial importance, and it was necessary to determine experimentally the optimum temperature of storage. This has been done. It is of interest to note that severe injury to the skin of an apple, as by cutting it in half, is followed by an increased output of carbon dioxide.

Effect of the Atmosphere.—Since the apple is alive, taking in oxygen and giving out carbon dioxide, it appears safe to conclude that the composition

of the atmosphere surrounding the apple must affect the storage life. If there is no oxygen present, the apple must die, and if there is an excess of oxygen it will live at a more rapid rate. An increase in the percentage of carbon dioxide in the atmosphere should, in general, retard the changes taking place in the apple, since carbon dioxide is the principal product of these changes. The experiments made by Hardy and those associated with him fully confirmed these conclusions, and as a result of their researches a new method of storing apples, known as 'gas-storage,' has been developed.

The relation of respiration to the supply of oxygen is somewhat complex. Supernormal amounts of oxygen in the atmosphere accelerate the occurrence of the climacteric, while subnormal amounts delay it. If the oxygen in the air, normally 21 per cent., is reduced to 5 per cent., respiration is minimal, the climacteric is definitely retarded and the magnitude is also greatly reduced. Moreover, in the later stages, oxygen appears to have a definite toxic action, and the maintenance of a subnormal concentration correspondingly prolongs the life of the fruit.

The effect of carbon dioxide is most important. It has no great effect on respiration in the pre-climacteric state, it markedly delays the onset of the climacteric, and in the post-climacteric state it depresses the rate of respiration. There is, however, a definite limit to the amount of carbon dioxide which apples can tolerate. If this limit is exceeded, a physiological disease known as brown-heart is produced. This disease was the cause of serious losses in shipments of apples from Australia and New Zealand before its cause was known.

There are therefore two simple methods of prolonging the life of apples: the application of cold—but it must not be too cold or the apple will break down and die; and gas-storage—but there must not be too much carbon dioxide or brown-heart will result and the apples will perish. Clearly, a combination of the two is the best solution, and such a combination is the basis of the recently developed method of gas-storage. There is, however, an interesting relationship between the permissible amount of carbon dioxide and the temperature: carbon dioxide reduces tolerance of cold, so that in its presence low-temperature breakdown occurs at temperatures which would otherwise be safe; while the lower the temperature, the smaller is the concentration of carbon dioxide that will produce brown-heart.

Application of Gas-storage.—I now come to application. I have already said that English apples are not very tolerant of cold. While certain varieties may be kept for six months at a normal cold-storage temperature of, say, 34° F., wastage from low-temperature breakdown occurs rapidly on removal from store—a serious matter, since, from a commercial point of view, an apple must keep in good condition for at least three weeks after removal from store to permit of marketing. Gas-storage has solved the difficulty.

I give as an example that most important cooking apple, the Bramley's Seedling. It was found that at a temperature of 41° F., well above the freezing-point, and with the oxygen in the atmosphere at 10 per cent. and the carbon dioxide also at 10 per cent., Bramley's Seedling apples could be kept in first-rate condition for twelve months, and, moreover, would retain their condition on removal from store for a period long enough to permit of marketing through the usual channels. This discovery, the work of Hardy and those associated with him, opened a new era in the storage of English apples, and one of which English growers were not slow to take advantage. The discovery is but a few years old, but to-day there are no

fewer than thirty-two gas stores in this country, with a total capacity of 7,000 tons, and the rate at which they are being erected is rapidly increasing. Further, while buyers were naturally sceptical of gas-stored fruit on its first appearance, it now commands a definite preference over ordinary cold-stored fruit.

The question ' Is the process expensive ? ' is often asked. The answer is ' No,' for it so happens that these conditions of 10 per cent. of oxygen and 10 per cent. of carbon dioxide are easily obtained in practice. Ordinary air contains 21 per cent. of oxygen, and apples will, if enclosed in a gas-tight store, soon use up half the oxygen, i.e. 10 per cent., and in doing so produce the 10 per cent. of carbon dioxide required. When that stage is reached, all that is necessary is to maintain it, which is effected by admitting fresh air in regulated quantities through simple ventilation.

But as different varieties of apples differ in their tolerance of temperature, so they differ in their tolerance of abnormal atmospheres, and it is necessary to determine the proper atmosphere for each variety by carefully controlled trials. This is naturally a slow undertaking, but twelve varieties, including English Cox's Orange Pippin, have now been covered. Soon it should be possible to obtain this latter variety, which I think is the finest apple in the world, at any time of the year.

Inhibiting Effect of Vapour.—One other point. I was careful to remark that the principal products of respiration of the apple were carbon dioxide and water. There are, however, other emanations, some of which are in minute quantities and have remarkable properties. For instance, if an attempt is made to sprout potatoes in air which has passed over apples, the growth is inhibited; peas and other seedlings are affected in the same way. On the other hand, the emanation actually accelerates the ripening of bananas and tomatoes. Whether the phenomenon will prove to be of great biological interest we do not know, but it has a commercial interest. The emanation from a ripe apple tends to hasten the ripening of young apples, and results in a colony of apples, as has long been known, ripening at about the same time.

Large-scale Experiments.—This lecture is necessarily incomplete. It is, indeed, little more than a ' motorist's glimpse ' of a large town as he bustles through it.

The experiments I have mentioned may have been pictured by you as small-scale experiments in a laboratory, and, indeed, the majority have been of that type. But control of temperature, carbon dioxide, and humidity, easy though they may be in a laboratory, are much more difficult in a great store, such as the hold of a ship. For a cargo of fruit generates heat, gives off moisture, and consumes oxygen and produces carbon dioxide. The heat, moisture and gas produced by the cargo must be removed, the gas by ventilation, and the heat and moisture by the refrigerating plant ; the importance of the scale of operation is obvious when we remember that the larger the cargo, the smaller, relatively, is the surface. Moreover, we are dealing with a case where a difference in temperature of half a degree, one per cent. more or less of carbon dioxide in the atmosphere, and a difference of humidity represented by a mere cupful of water, may turn success to failure.

Special attention is given to these scale effects and other problems connected with the transport of fruit at sea in an experimental ship's hold at the Ditton Laboratory in Kent. This experimental hold, the only thing of its kind in existence, has a capacity of 120 tons. Such a hold is an expensive piece of apparatus, but the results obtained are of great value, and I venture to think it has already more than paid for itself.

Conclusion.

The result of Hardy's work is with us to-day. It can be seen in the great ships which carry meat and fruit to our shores, in our cold stores, in the commercial gas stores for apples and in the fish markets. If Hardy were with us to-night, he would, I know, in his characteristic manner, give all the credit of his achievements to those who worked with him ; to those brilliant men he collected together at Cambridge, at Torry, at Ditton, and to others at the National Physical Laboratory. And last, but not least, he would have thanked those who helped and advised him as members of the Food Investigation Board. But certain it is that all these would be the first to agree that the credit is Hardy's. He was at the helm, and it was he, more than all the others, who was responsible for the planning and development of the work, a task which gave full scope for the exercise of his remarkable powers. Truly Hardy was a great man ; we shall not see his like again.

SECOND EVENING DISCOURSE.

MONDAY, SEPTEMBER 10, 1934.

THE EXPLORATION OF THE MINERAL WORLD BY X-RAYS

BY

PROF. W. L. BRAGG, F.R.S.

(1) THE mineral world has supplied us with many of the most beautiful examples of crystal structure. Crystals grow best when the growth takes place in very constant conditions and very slowly, and these conditions are fulfilled in nature in a way that cannot be rivalled in the laboratory. The beauty of natural crystalline forms has always attracted attention, and some of the rare and durable varieties have been prized, as jewel stones, as the most valuable of all natural objects.

Crystalline arrangement is not confined, however, to such well-developed specimens as are displayed in mineral collections. Ruskin, in his *Ethics of the Dust*, draws his moral from the exquisite patterns which would be revealed if we could magnify up sufficiently any speck of dirt. The *Ethics of the Dust* is a series of lectures in which the theme is based upon the varieties of mineral species and the ordered arrangement of the atoms which compose them. Ruskin pictured his listeners gifted with a power of vision which enabled them to see the arrangement, and made a series of guesses about its nature. Now that this power of vision has become a reality, and we are able to study crystal patterns by means of X-rays, it is remarkable to see how close to the truth his imagination, unhampered by scientific caution, often led him.

The present is a suitable time to review our knowledge of the structure of the mineral world, because all the main types of minerals have been analysed. The existence of any well-crystallised mineral has always been a challenge to those whose research is the analysis of crystals by X-rays. Nature provides us with such excellent material on which to exercise our technique. The first crystals to be analysed were minerals, rock salt, diamond, fluor, blende, pyrites and calcite. For twenty years the enquiry has been pursued, and with the recent analysis of the felspars it may be claimed that the main survey has been completed. There are, of course, many fascinating points of detail still to be investigated, but we can summarise the general laws which govern the different structures composing the solid crust of the earth.

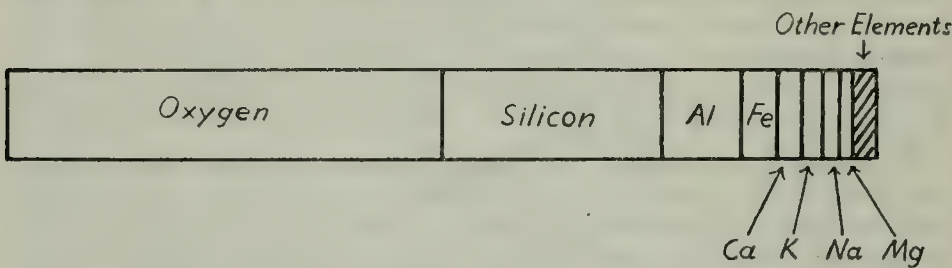
(2) We may first enquire how it is that we are able to speak of minerals as a limited class of chemical compounds. The number of compounds that can be formed from the chemical elements is endless. Yet the number of mineral species is restricted, and if we except the rare kinds which are found in odd corners where very special conditions have existed, the number is quite small. It must be admitted that part of the interest in mineralogy has been the interest of the collector. The fun of making a collection would be spoilt if nature kept on producing endless new varieties of minerals,

just as the fun of postage stamp collecting of our boyhood has been spoilt for our children by the vast numbers of issues in which countries now indulge.

The minerals are limited in number because they are the last survivors of the wear and tear of ages. They represent matter in the ultimate state of equilibrium. They have sunk into so deep a pit of low potential energy that no chemical change can tempt them to desert it.

This state of lowest potential energy is one of order and not of disorder. A crystal is more stable than a jumble of atoms. The perfect geometrical arrangement of a crystal represents matter in its most dead and inert form, from which nothing further in the way of change can be expected, just as the various utopian schemes of society which have been put forward from time to time represent the most dull state in which it is possible to conceive living.

The world we are to study, then, is to be ruled by the laws of geometry. We will speak of tetrahedra, octahedra, angles, faces and edges. To appreciate this world, we must be like the Greek geometers who were ravished by



Oxygen 50 %	Silicon 26 %	Aluminium 8 %	Iron 4 %
Calcium 3 %	Potassium 2·5 %	Sodium 2·5 %	Magnesium 2 %

Total 98 %

FIG. 1.—Relative abundance of common elements.

the beauty of the symmetrical solid figures. In no other science do these geometrical figures play so important a part, they are peculiar to crystallography. Though all crystals are based on geometrical patterns, the simplest regular geometrical forms are of outstanding importance in mineralogy just because minerals are so extremely inert. The condition for low potential energy imposes upon their configurations certain geometrical requirements, which are broken by the ephemeral compounds we prepare in the laboratory.

(3) Eight elements compose 98 per cent. of the earth's solid crust. In our broad survey, we will neglect all the other elements, most of which only occur in odd cracks here or there where we laboriously search for them. The common elements are oxygen, silicon, aluminium, iron, calcium, potassium, sodium, and magnesium. Their proportions are shown in Fig. 1.

The bulk of the crust is oxygen. Not only is it the commonest element, but also it takes up the most room. The rocks are made of oxygen atoms cemented together by silicon, aluminium, and a few other elements. According to the way in which they build up structures with oxygen, these elements are divided into three classes, to which we will have frequent occasion to refer.

(*a*) Elements forming the centre of a *tetrahedral* group. Four oxygen atoms are grouped together at the corners of a tetrahedron, and the element

is situated at the centre. All the silicon is in this situation, and by far the greater part of the aluminium.

(*b*) Elements forming the centre of an *octahedral* group. Six oxygen atoms are grouped at the corners of an octahedron, with the element at the centre. This is the characteristic situation for magnesium and iron, and also for the remainder of the aluminium. Aluminium is peculiar in that it can play a double role, generally grouping itself with silicon, but sometimes behaving like the metals iron and magnesium.

(*c*) The bulky elements sodium, calcium, and potassium. These elements are too large to be placed in tetrahedral or octahedral groups. They are accommodated in large, often irregular, holes in the structure.

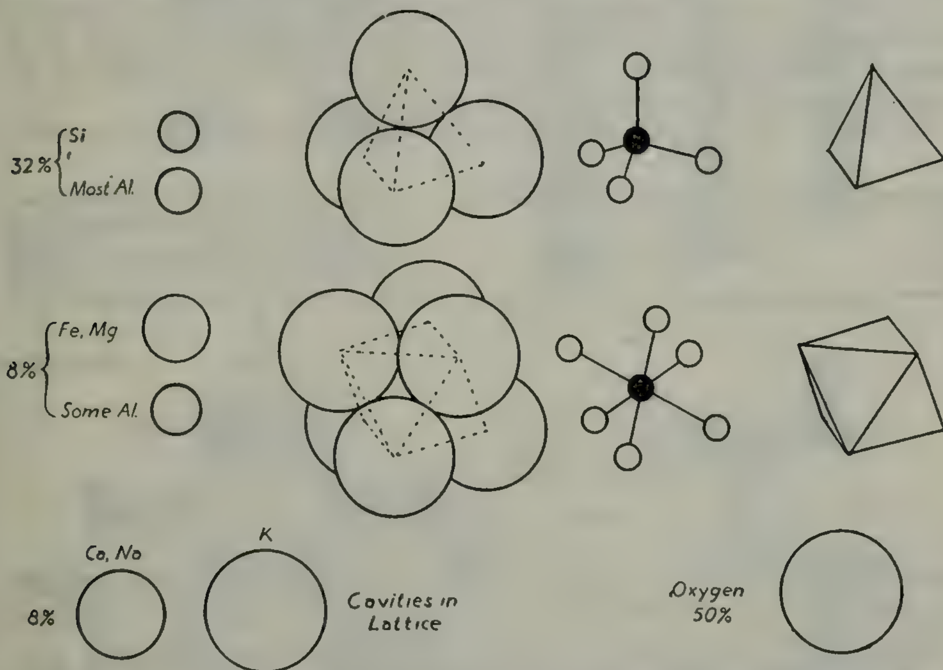


FIG. 2.—Association of common elements with oxygen in mineral structures.

The types of group are illustrated in Fig. 2. The tetrahedral and octahedral groups are the fundamental units of pattern, the stitches of which the mineral fabric is composed. All the common minerals, however complex their patterns, are a framework of these tetrahedral and octahedral groups. It must be realised that the groups are not distinct units, for there are not enough oxygens for each central atom to have its complete group belonging to it alone. The oxygen atoms of one group also form part of the next. It is very convenient to use the tetrahedra and octahedra in describing the structures, but it must be remembered that these units have common corners, edges, or even faces, because an oxygen atom of one also belongs to another. In this way the whole structure is knitted together.

(4) The common minerals are divided into certain large groups, and in making his classification the mineralogist has in the past been guided by physical properties and form rather than by chemical constitution. A study of the structure of minerals has amply justified this allegiance. It is now seen that the basis of the classification is a kind of skeleton of the mineral structure, composed of the linked tetrahedral groups. These links are stronger than the octahedral links, and very much stronger than the links of

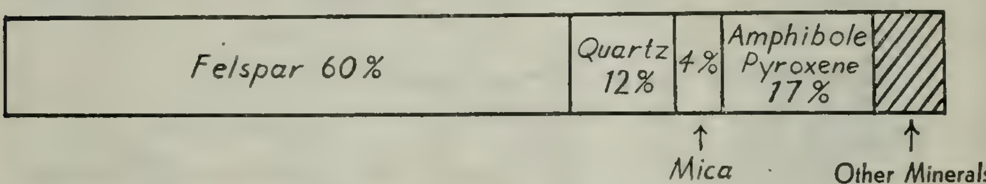
the bulky elements Ca, Na, K. The tetrahedral framework is the hardest part of the mineral, its skeleton, and it has the chief influence in deciding the form of the structure.

The relative abundance of the most common minerals is shown in Fig. 3. The minerals are quartz, felspar, mica, pyroxenes and amphiboles. The basic ferro-magnesium silicates such as olivine may also be included. These great natural divisions of minerals have strikingly different physical characteristics, and are built up as follows :

(*a*) *Olivine* (Mg, Fe)SiO_4. The SiO_4 tetrahedra are not linked directly to each other, only by intermediate octahedral groups round Mg or Fe. (Fig. 4*a*.)

(*b*) *Pyroxenes and Amphiboles.* $MgCa(SiO_3)_2$, $Mg_5Ca_2(Si_4O_{11})_2(OH)_2$. The tetrahedral groups are linked into endless chains by stringing them together corner to corner. These chains are held together sideways by magnesium and iron octahedra. (Fig. 4*b*.)

(*c*) *Micas.* $K(Al_2, Mg_3)(AlSi_3O_{10})(OH)_2$. The tetrahedral groups,



	Felspar	Quartz	Mica	Amphibole Pyroxene	Olivine
Density	2·75–2·55	2·65	2·86	3·3–3·1	3·4

(Cp. Blende 4, Pyrites 5·1, Copper Pyrites 4·2)

Fig. 3.—Relative abundance and densities of common minerals.

containing both Si and Al, are linked into endless sheets. These sheets lie on each other like the leaves of a book, and are bound together in various ways. (Fig. 4*c*.)

(*d*) *Felspars.* $KAlSi_3O_8$, $NaAlSi_3O_8$, $CaAl_2Si_2O_8$. The tetrahedra form a framework in three dimensions, each tetrahedron being linked by every corner to another. The framework has the composition (Al, Si)O_2. The bulky ions K, Na, Ca are in open spaces within it. (Fig. 4*d*.)

(*e*) *Quartz.* SiO_2. This is a structure composed entirely of tetrahedra containing Si, linked everywhere corner to corner.

Typical structures are shown in a diagrammatic way in Fig. 4.

The type of structure corresponds to the composition of the mineral, in particular to the ratio of the first group of elements (those inside tetrahedra) to the available oxygen. For instance, if there are four oxygens or more to every silicon we have separate SiO_4 groups. If there are only two oxygens to every silicon, the tetrahedra must share *every* corner in order that each Si may have four oxygens around it, and the structure of quartz is the result. The intermediate types of linking represent intermediate ratios :

(*a*) SiO_4	Separate SiO_4 groups	Olivine
(*b*) SiO_3	Single chains	Pyroxenes
Si_4O_{11}	Double chains	Amphiboles
(*c*) $(Si,Al)_2O_5$	Sheets	Mica
(*d*) $(Si, Al)O_2$	Networks	Felspar
(*e*) SiO_2	Networks	Quartz

(5) We may now consider some properties conferred upon the minerals by these characteristic forms of grouping.

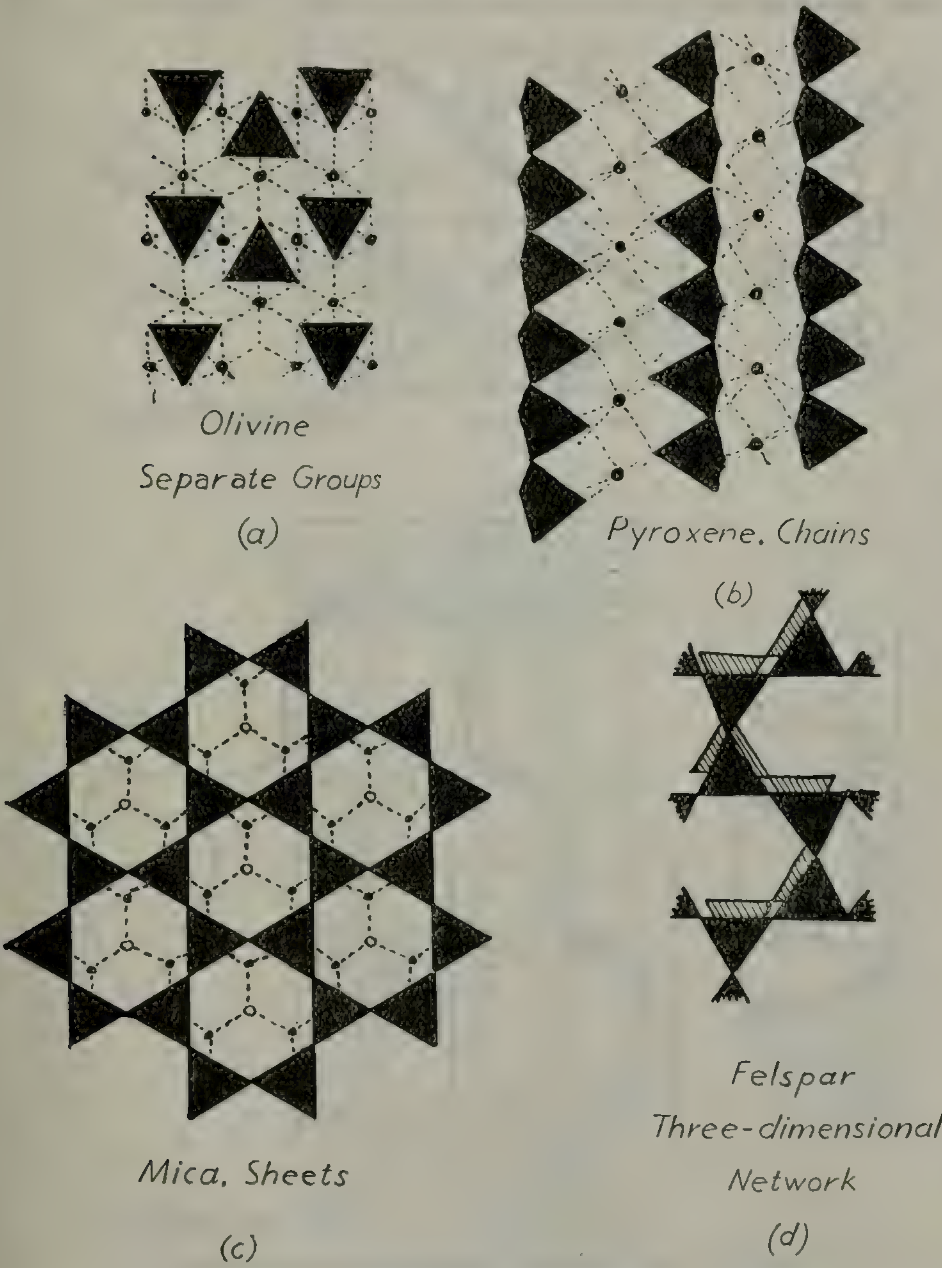


FIG. 4.—The arrangement of the (Si, Al)—O tetrahedra in the common minerals. Tetrahedra are silhouetted in black.

(*a*) *Olivine.*—In olivine the separate SiO_4 tetrahedra are linked together by Fe and Mg octahedra. It is geometrically possible to do this in an extremely compact way, without wasting any space. The mineral is also very uniform in texture, since there are no exceptionally strong bonds

in one direction rather than another. Hence we have a heavy compact mineral of a glassy texture.

(*b*) *Pyroxenes and amphiboles.*—These are composed of strings of tetrahedra, linked side by side by the Fe and Mg octahedra. As is to be expected,

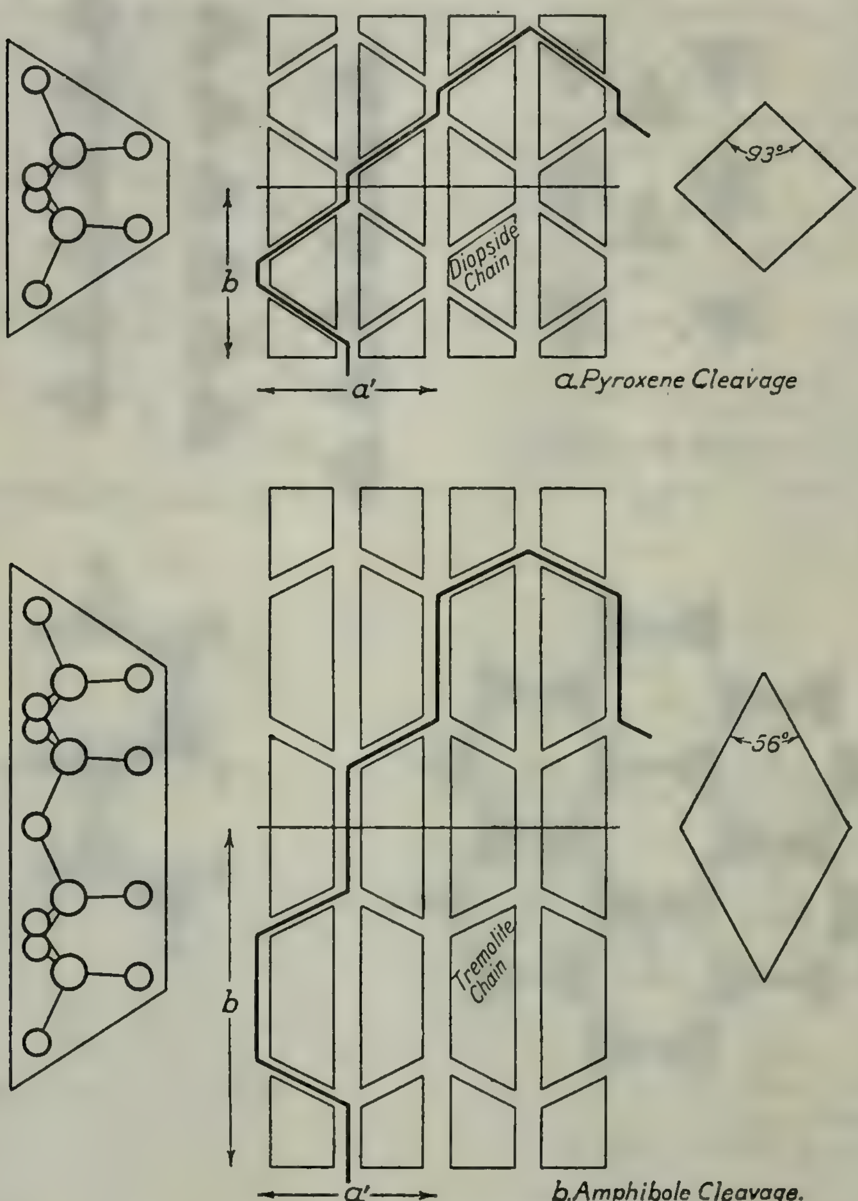


FIG. 5.—The cleavage of pyroxenes and amphiboles.

they are all fibrous in nature, splitting very easily along the chains but not across them. *Asbestos* is a well-known example of such a mineral. Asbestos fibres are most remarkable. One can tie an overhand knot in a fibre and pull it tight without breaking it, just as one can with a cotton thread. Familiarity lessens our surprise, but it is really extraordinary that a knot can be tied in a stone with such ease. This property arises from the very

Fig. 6(*a*).—The growth of NH_4I on mica (lepidolite). A sub-microscopic step on the mica sheet separates the two areas where the NH_4I crystals point in opposite directions. Each area is a true plane to within a single molecule. ($\times$ 80)

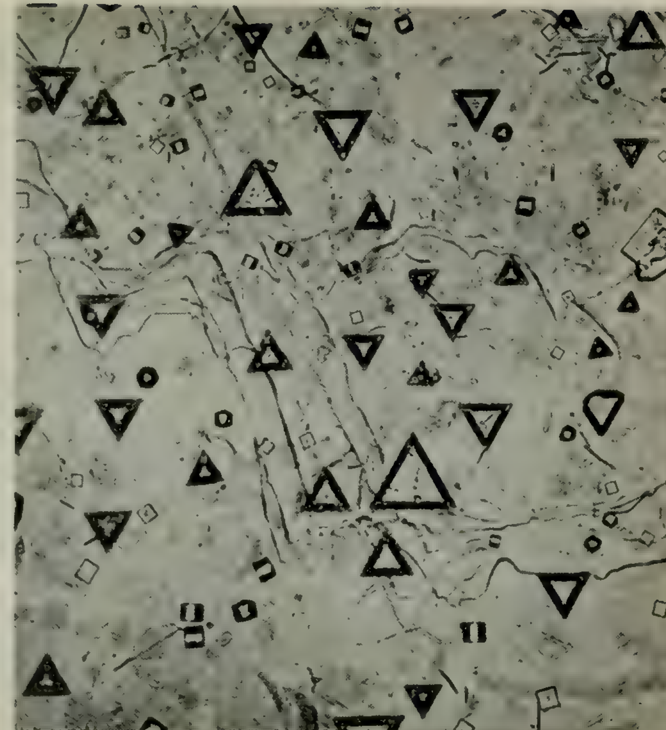


Fig. 6(*b*).—A similar phenomenon on phlogopite. The crystals of NH_4I point either way at random ($\times$ 80)

Illustrating Prof. Bragg's Discourse: The Exploration of the Mineral World by X-Rays. Photographs by Mr. C. W. Bunn, Imperial Chemical Industries, Research Laboratory, Northwich.

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strong bonds in the tetrahedral groups, and the relatively weak links which bind the chains together.

These minerals are divided into two great classes, the pyroxenes and amphiboles. They are distinguished by their cleavage. The cleavages cross each other at about 90° in the pyroxenes, and 56° in the amphiboles. The reason for this difference was discovered by Warren, and his explanation is illustrated in Fig. 5.

All pyroxenes are based on single chains of tetrahedra, all amphiboles on double chains, two chains being linked side by side to form a kind of tape. In the figure, we are looking at the chains end on, and it will be seen that the amphibole chains have a much more oblong cross-section. The consequence is that the cleavage cracks, in avoiding cutting the chains, cross each other more obliquely in the amphiboles.

(*c*) *Mica.*—Sheets of mica cleave with extreme ease. A sheet can be split again and again into thinner lamellæ in an apparently endless way.

The model of mica which I have here shows its structure, first analysed by Pauling. The main feature is a series of sheets of tetrahedra, each tetrahedron being linked by three corners to neighbours to form a hexagonal network. Two such sheets are then linked together by Al, Mg, or Fe octahedra to form a composite sheet. It is these double sheets which are so immensely strong, and enable mica to be cleaved so easily, because each is only fastened to its neighbours on either side by the weak attractions of potassium atoms lying between them.

The perfection of the mica cleavage is a truly remarkable phenomenon. It runs along the plane where the potassium atoms are situated, and may run for a centimetre or more without deviating from this plane by a single atom. We can show this, as Friedel first pointed out, by growing crystals of $(NH_4)I$ on the mica. The ammonium atoms in NH_4I happen to have precisely the same arrangement as the K atoms in mica, both in shape and scale. In consequence, the NH_4I crystals all grow in parallel orientation on the mica. The grain of the pattern in successive molecular sheets of mica points alternately to right and left of its symmetry plane, hence the little crystals of NH_4I also point to right or to left depending on which type of sheet forms the top surface of the mica. If they all point the same way, the top sheet must be the same all over the surface. Fig. 6 shows a mica surface in two steps, all the crystals pointing one way on one side and in the reverse direction on the other.

The 'grain' is less marked in micas (biotite, phlogopite) with the formula $K(Mg, Fe)_3(AlSi_3O_{10})(OH)_2$, than in micas (muscovite) with the formula $KAl_2(AlSi_3O_{10})(OH)_2$; hence in the former case the NH_4I crystals point indifferently in either direction.

The mica-like sheets form the basis also of the *clay* minerals. These are single sheets of tetrahedra with an active side of vertices and an inactive side of bases. The clay minerals are little hexagonal spangles, a kind of mineral 'leaf-mould' formed by the breakdown of other rocks. Their curious chemical and physical properties, so important to the soil, are the result of their platy character.

(*d*) *Felspar.*—This is the most important mineral of the earth's crust. We are familiar with it as a main constituent of granite. It is composed of Si and Al tetrahedra linked by every corner in every direction, a three-dimensioned latticework of tetrahedra. The bulky atoms Na, K, Ca are immeshed in its interstices.

We may only refer here to two of its interesting properties. In the first place, if we make a structure of tetrahedra linked by all their corners in this way, it is geometrically impossible to fit octahedra on to it. In

consequence, magnesium and iron, which are characteristically in octahedral groups of oxygen atoms, are excluded from the felspar structures. We never find these metals in felspar.

In the second place, the felspars are divided into two great families. The more symmetrical orthoclase, $KAlSi_3O_8$, is typical of the one family, and the less symmetrical albite and anorthite, $NaAlSi_3O_8$ and $CaAl_2Si_2O_8$, of the other. The difference is simply a question of the size of the large cation. Potassium is so large that when inserted into the framework it holds it distended into the symmetrical form, whereas the smaller Na or Ca allow it to sag over into a lop-sided unsymmetrical shape. This explanation is due to Taylor, who first analysed the felspars.

(6) Finally, I wish to refer to another broad feature of minerals, their *densities*.

The densities again depend to a large extent upon considerations of geometry. If we pack isolated tetrahedra together with octahedra, as in olivine, space can be utilised in a most economic way. It is geometrically possible to arrange the structure so that a maximum number of oxygen atoms, with their concomitant cations, are included in a given volume. On the other hand, building up a structure by attaching tetrahedra corner to corner is most wasteful as regards volume. It produces an expanded structure containing large open spaces.

In consequence we find that olivine is the heaviest, and felspar and quartz are the lightest, of the common minerals, others being intermediate. The greater the extent of the tetrahedral linking, the lighter the structure, as the following list shows :

	Density.
Olivine	3·4
Pyroxene, amphibole	3·3–3·1
Mica	2·85
Quartz	2·65
Felspar	2·75–2·55

The fact is, of course, that the earth's crust is mostly composed of these minerals, with felspar and quartz predominant, just because they are the lightest and so float to the top. The light felspars float on the heavier ferro-magnesian silicates, and these in turn probably on metallic sulphides and metals which are much denser. Geometry is again triumphant. The fortunate existence of a raft of rock on which life is possible is seen to be a result of the geometrical properties of tetrahedra and octahedra.

PHOTOELECTRICITY, ART AND POLITICS: AN HISTORICAL STUDY

BY

N. R. CAMPBELL AND C. C. PATERSON, O.B.E.

(*Ordered by the General Committee to be printed in extenso.*)

UNTIL a few years ago any speaker addressing the general public at the meetings of the British Association for the Advancement of Science regarded it as one of his chief duties to plead that science should play a larger part in the affairs of the nation. But of late a new note has been evident in our discourses. We have all come to realise that science may be abused as well as used, and that some of the evils of our present state to which our thoughts are most constantly directed arise from that abuse. Whether we discuss war or unemployment, we cannot ignore the social effects of our increasing scientific knowledge. We are not quite so sure that science is the unmixed blessing that we once believed it to be.

Some bold spirits have no qualms. They conduct a vigorous counter-attack and urge that such evils as have arisen are due to a half-hearted use of science. If we were only consistent and would hand over the conduct of all our affairs to the charge of fully instructed scientists and engineers all our difficulties would vanish. We may readily admit that there are large regions of immense social import that lie barren for lack of public interest, and that there are still those who think that ignorance of science is the first qualification of the statesman and the administrator. While such things remain, the work of this Association will never be done. Nevertheless many of us feel that there is another side to the question, and should be happier if our champions were readier to distinguish between the value of science and the merits of scientists.

For if the value of science is stated quite impersonally, it becomes clear that the problem is not one with which scientists, as such, have any concern. In its application to practical affairs, scientific knowledge is merely a means whereby man may fulfil his desires. Its results will depend on the nature of those desires. In determining them scientists have, and should have, no greater influence than any other body of citizens ; they are not actually united in their social and political aims, and, if they were, their special interests might not coincide with the good of the whole community. The business of scientists is to provide the means ; the determination of ends belongs to the political institutions of the state.

But this assumes that science is not more likely to provide means for bad ends than for good. Those who regard all material satisfactions as bad would no doubt dispute that ; but they are all either monks or millionaires, and our words will not reach them. However, the assumption may also be denied for a rather subtler reason, which demands our attention. It might be urged that science favours the bad rather than the good, because the changes that it induces are sudden and unexpected. Communities, like individuals, need time to think ; if presented with an unexpected situation, they act by instinct, which is always self-regarding, and not by

reason. If only the stream of invention and discovery could be slowed down, so that the community had time to accustom itself to each new power before it was presented with the next, it would be far less likely to abuse them. Hence we get pleas for a scientific truce, during which no more advances in knowledge should be made. The objection to such a plan is, of course, that it is impracticable ; its execution demands a greater, not a less, unity and consistency of purpose than some less drastic method of control. Prohibition is of all regulations the most difficult to enforce. Even if it is true that the suddenness of science is the main source of our troubles, it does not follow that a speed limit is the proper remedy. A better plan may be to exercise a greater foresight.

We do not pretend for a moment that it is easy to foresee the direction that discovery and invention are likely to take even in the immediate future. One of the chief duties of an industrial research laboratory is to assist in such forecasts, and we are very conscious how easy it is to make mistakes. But, on the other hand, it is not quite so difficult as the public are often led to believe. Novelty has its own attractiveness ; and people with new devices to sell always use the romantic appeal of the great invention springing suddenly from the brain of a single genius. But most inventions hailed with a blare of trumpets as the latest epoch-making marvel are not matters for sentiment. Either they are comparatively trivial modifications of old devices, which any well-informed engineer has long known to be inevitable ; or they are incomplete suggestions, thrust into prominence long before they are due, vanishing from the public memory as quickly and as suddenly as they appeared.

All inventions that influence greatly the course of history have themselves a history behind them. And the histories of many inventions have much in common. If we want to guard ourselves against surprise in the future, we should study the past and apply its lessons. If is for this reason that we have been asked to invite your attention to-day to the history of one particular invention or discovery. We are not sure that its lessons are very obvious ; perhaps we are not in a position to see tham ; the engineer himself may not be able to see the wood for the trees and must leave it to the trained historian to draw conclusions. We shall try simply to tell the story, and shall make only the simplest and most obvious reflections.

There are several reasons for choosing the photoelectric cell as an example. The first is that the history is exceptionally long and complicated. That statement may surprise those of you who have just heard of photoelectric cells and regard them as one of the marvellous products of the last few years. Nevertheless it is true. We shall have to start our history sixty years ago, and shall find that the development of cells themselves, as distinct from their accessories, was almost complete forty years ago. No better example could be offered of how the general public are misled by those who are so busy making history that they have no time to read it.

The second reason is that the results of the applications of photoelectricity hitherto have been comparatively trivial. They have not aided the struggle against disease and poverty ; and on the other hand they have not provided weapons for war or displaced large quantities of labour. In discussing them our passions will not be aroused, and we can consider with detachment their potential, and perhaps their future, effects, which might have been or may be considerable.

And now what are photoelectric cells ? As their name implies they are devices for turning light into electricity ; or more accurately, devices in which the incidence of light produces or changes an electric current flowing in some circuit. We are not going to discuss their action in detail ; for

scientific explanations are irrelevant to our theme. But we must make two points clear. The existence of photoelectric cells is no accident ; it arises from the most fundamental properties of light and electricity. In the view of modern physics light is no longer a discrete agency separable from its origins and its effects. To say that light is issuing from a source A and falling on a body B is merely a loose way of saying that electrical changes in A establish a certain probability that similar electrical changes will occur in B. In a very real sense all actions of light are photoelectric ; the question is not how the light that we see can be used to produce electricity ; it is rather how the electrical changes that are the primary effect of light come to produce vision. Although the sequence of discovery still seems to us irregular, we can see now that any prolonged study of light must have led to the discovery of photoelectricity, and that by the end of the eighteenth century it was already inevitable.

Again, although all photoelectric effects are in essence the same, superficially they are different. At the present time four different kinds of photoelectric cells are generally distinguished : conductive cells, emission cells, voltaic cells, rectifier cells. Each kind has its own advantages and limitations ; but to these we shall not often refer ; in many fields the different kinds are mutually replaceable, at least in principle. Photo-voltaic cells are the oldest ; the phenomenon that they use was discovered by Becquerel in 1839. But the discovery had no practical consequences at the time ; and the use that was made of it much later (but then only temporarily) was not really based on the original discovery. On the other hand rectifier cells were discovered as lately as 1926, when all the principles underlying modern applications were already established. They are of very great importance, and make some applications much easier ; but they arrived too late to affect the main course of photoelectric history, which was determined by the discoveries of conductive and emission cells.

Conductive cells were discovered by Willoughby Smith in 1873. In connection with work on telegraph cables, he was seeking a substance of high electrical resistance. He thought he had found what he wanted in the element selenium, a relatively rare substance resembling sulphur, which had been known for many years, but little investigated. However, he found that the resistance was very variable, and he soon tracked down the variations to changing illuminaton. Selenium when illuminated decreased in resistance ; the greater the incident light, the greater the current that flowed in the circuit containing the selenium resistance.

The practical implications were realised immediately ; and by 1880 invention was in full swing. In fact the volume of the *Electrician* for 1880–1881 devotes a larger proportion of its space to photoelectricity than any other volume we have examined. Let us consider what was the state of the electrical art at that time.

The chief industrial use of electricity was still in communication. The *Electrician* gives in each number the prices of telegraph shares, but of no others. And there is great excitement over the legal action between the Post Office and telephone companies, in which Mr. Justice Stephen decided, in the face of expert opinion, that a telephone was a telegraph within the meaning of the Act. (Most of the experts are, of course, long dead ; but Dr. Fleming, in the guise of Sir Ambrose, is still with us ; we wonder if he remembers supporting Stokes in his declaration that there is nothing in common between the two instruments and asserting that a telephone was nothing but a complicated kind of speaking trumpet !) Of course there were other interests ; for the foundations of most branches of electrical engineering were laid between 1873 and 1880. Arc lamps were actually

being used and incandescent lamps were just becoming practical. But the public were apparently more interested in watching the furious dispute between Edison and Swan over the priority of their inventions of the incandescent lamp than in considering the worth of what they had invented. Communication was the real field of practical electricity.

It was no accident, therefore, that the first photoelectric cells were a bye-product of telegraphy ; but the natural result was that the first thoughts for their use were all in the same field. In 1880 the leading inventors are Graham Bell with his photophone and Shelford Bidwell, Senlecq and others with their systems of telectroscopy, telephotography and the rest. The photophone is one of those inventions which are made regularly every few years, and as regularly forgotten. The idea is to cause sound to vary a beam of light in accordance with its vibrations ; to throw the varying beam of light on a photoelectric cell, so as to produce there corresponding variations in an electric current ; and to reconvert these variations of current into sound by means of a telephone. The scheme is quite practicable, but its value was not obvious. It might be used to transmit sounds between stations that can be connected by a beam of light, but not by a pair of wires ; in other words it would give wireless telephony, restricted to people who can see each other ; it might be possible, for instance, between neighbouring ships at sea. But even to-day this plan is difficult to carry out except in favourable circumstances—and then there are usually better alternatives. The other use, also foreseen from the start, is to help the blind. Here the first stage is omitted ; the variations in light turned into sounds are not those arising from sounds, but such variations as normal people see ; they are turned into sounds only for the purpose of those who cannot see. Such schemes excited the enthusiasm of Fournier d'Albe some thirty years later ; he hoped by this means to enable blind people to read an ordinary page of print. A beam of light scans the lines of print and produces sounds in a telephone as it passes from black to white and *vice-versa* ; these sounds are determined by the shape of the letter, so that by training the letters can be recognised by the sounds. The instrument developed on these lines by Barr and Stroud from the ideas of Fournier d'Albe really worked ; but alas ! it has proved too cumbrous and expensive to give blind people much assistance.

The other great scheme of the seventies, telectroscopy or telephotography, is what we now call picture-telegraphy and take as a matter of course when we read our newspapers. Forty years had to elapse before it became really practicable; but the problem was conceived quite clearly and accurately in these early days ; methods of scanning and synchronisation, which are still the clues to success, were carefully discussed. In some respects the men of that time were curiously modern ; for instance they thought of the Kerr cell for modulating the light at the receiving end ; most people probably regard that as an essentially modern instrument. Indeed they went further and envisaged television, realising its possibilities and some of its difficulties. Television differs, of course, from picture-telegraphy in that the image has to be produced visibly at the receiving end simultaneously with its transmission and not after an interval during which a picture is produced. Ayrton in a lecture on ' Seeing by Electricity ' laid down in 1880 some sound principles which workers of our own day have sometimes forgotten, though he admitted that they could not immediately be converted into practice.

The great obstacle to progress in those days was the absence of any method of amplifying currents such as we now derive from the thermionic valve. Indeed the mere idea of amplification was absent. The last relics of the old difference between frictional and galvanic electricity do not seem to have

disappeared completely ; the essential identity between currents from all sources and from all magnitudes does not seem to have been duly appreciated. Thus nobody seems to have seen that the large currents of low frequency required for synchronisation might be transmitted by the same channel as the small currents of high frequency obtained from the photoelectric cell. The point that we want to make is that men's vision was limited in both directions by the general outlook of their time. They saw very clearly the possibilities of photoelectricity for communication, because their thoughts naturally tended in that direction ; but they failed to appreciate what further elements were required to turn possibility into reality, and therefore could not look in the right direction for those elements. Meanwhile they failed to think of applications which were wholly or quite within their grasp.

We turn now to the second kind of cell, the emission cell. The fundamental fact here is that light falling on metals causes them to emit a current of electricity, in the form of a stream of electrons ; this can be collected, made to pass round an exterior circuit and produce there any electrical effect desired. Here we may note a difference between the two kinds of cell that may appear at first sight to be important. In the photo-conductive cell the energy of the current has to be derived from a battery or some source other than the light ; in the emission cell it can be derived from the light itself. The emission cell therefore affords in principle the possibility of converting sunlight directly into electric power without passing it through our present wasteful intermediate stages, such as the growing of vegetation which we subsequently burn, or the raising of water to fall and fill rivers. But actually nothing has been achieved in that direction even to-day. The difficulty is one of mere size. With a cell of given area, we cannot produce more power than falls on that area from direct sunlight in the most favourable conditions. The amount of power incident on one square yard of the earth's surface in the most favourable conditions is never more than one kilowatt ; the average received in our climate is not more than one hundredth of that amount. If you work out a sum of proportion you will find that to collect the electrical power used in this country, an area at least as large as London would have to be covered with photoelectric cells ; and even if we drew our power from cloudless regions the cells would occupy the area of a large town. Now photoelectric cells are somewhat delicate instruments ; and although they need no longer be enclosed in a vacuum, like emission cells, it is quite impracticable to make cells of that size. If we tried to use many cells of the kind now made, we should require about 5,000 million of them ; each costs several shillings at least ; and then we should waste most of our power in connecting them. No ; when we have to harness natural forces, we are still forced to resort to nature's crude and wasteful, but effective, machinery.

But that is a mere aside ; we must continue the story. The history of emission cells, like that of conductive cells, begins with an accident. Hertz in 1887, when working on electromagnetic waves, found that the incidence of ultra-violet light on a spark gap made it easier for a spark to pass across it. Hallwachs in the next year found that the change was due to a current flowing from the metal of the gap under the action of the light. He thus established the fundamental fact, although of course he did not know that the current was carried by a stream of electrons, for electrons were not then known ; the effect on which emission cells depend was therefore called the Hallwachs effect. But the real parents of emission cells are Elster and Geitel who started their work in 1889, and by 1894 had developed the cells to a state that remained substantially unchanged for more than thirty years.

Hallwachs had worked with ordinary metals and had found his effect only

with ultra-violet light. Elster and Geitel showed that visible light would produce the same effect in the ' alkali ' metals, sodium and potassium, which can exist in the metallic state only if preserved from contact with the air. They devised methods of handling the metals in a vacuum—for all our modern vacuum technique is long subsequent to their work ; they investigated with great care the relation between light and current with a practical purpose that we shall notice later, and they invented the ' gasfilled ' cell, in which the primary photoelectric current is amplified by passing through an inert gas. Their work was magnificent ; how magnificent only those know who, after a generation, have tried to follow in their path. Even the last ten years, when interest has been world-wide and inspired by vastly fuller knowledge, have added only a few inessential details to their achievement.

And yet it remained almost unnoticed. Unlike the far less thorough work of Willoughby Smith and his immediate successors, it produced no spate of invention. It was quite unnoticed by engineers. For thirty years engineers, if they thought about photoelectricity at all, thought of it in terms of the selenium cell ; and even to-day many partially informed people imagine that all photoelectric cells contain selenium. There was perhaps some excuse. For the currents obtainable from emission cells are markedly smaller than those obtainable from conductive cells ; and it was the smallness of even these currents which stood in the way of their application. But the real reason was one of atmosphere.

Elster and Geitel were physicists, not engineers. Their cells were born in the atmosphere of ' pure science '—an unfortunate term, but there is none better. And as the seventies were the great period of electrical engineering, so the nineties were the great period of pure science. Modern physics, a wholly new science, was born in that decade. It is usually dated from Röntgen's discovery of X-rays in 1895, which led to the study of the electrical properties of gases, to the discovery of the electron, to radioactivity, and to all of that vast field of new facts concerning the interior of the atoms which finally led in our own day to the revolutionary theories by which alone they can be explained. In that great advance the Hallwachs effect has played an essential part. The facts on which emission cells rely were probably the most powerful arguments for rejecting the mechanical theories of the older physics and for accepting the bewildering ideas of quantum theories. The theoretical implications of this branch of photoelectricity completely overshadowed its practical potentialities ; emission cells were regarded as laboratory curiosities, productive of nothing but a welter of contradictory philosophies, no concern of a self-respecting engineer!

Ten years ago, fifty years after the dawn of photoelectricity, its sun had apparently set. Photoelectric cells were being used to some small extent in laboratories and observatories ; but elsewhere, although interest in it had never really ceased, its prospects were very dim. Photoelectricity had appeared before the world was ready for it. Inventors had lost heart because they had tried to run before they could walk, and because they had failed to keep abreast of knowledge outside their immediate view.

And then the unexpected happened, as it always does. In 1926 talking films were issued from Hollywood. They took a little longer to reach England. The first joke about them we have found in *Punch*—that invaluable record of our social history—occurs at the end of 1928 ; it is difficult to realise how recent they are. Now there was nothing new in the idea of associating sound with the moving picture ; it had been proposed and actually achieved in quite the early days. For the technical means were already to hand in the gramophone, which, of course, antedates the moving

picture. Any well-informed engineer, trying to forecast the course of invention in 1920, might have foretold that the sound film would come; but he would probably not have guessed that photoelectric cells would play any part in it; he would probably have looked to the gramophone to provide the sound.

However, there was another possibility in the oft-invented and oft-forgotten photophone. That you will remember is an instrument for converting variations of light into sound by means of photoelectric cells. If it were to be used for this purpose, the sound to be reproduced had to be recorded in the form of potential variations of light. Now this problem had actually been studied in the early days of the photophone; methods had been devised for recording the vibrations of sound in the form of cyclical variations of density in a photographic plate, so that when the plate was passed across a beam of light, the light would vary in accordance with the sound vibrations. We will not stop to explain how this is done; there are several methods; and the remarkable thing is that all of them were invented in principle round about 1880. But they were greatly developed in the first ten years of this century for the purpose of studying sound. Accordingly methods of recording sound in a form from which it might be reproduced by the photophone were already available.

By the early twenties several people had seen that here was an alternative to the gramophone for associating sound with the talking picture. Perhaps the most energetic was de Forest, whose name will always be associated with the audion, the first thermionic amplifier. By 1923 he had really succeeded in printing on the same film with a moving picture a sound record which produced recognisable sounds; but the reproduction was definitely not as good as that of the contemporary gramophone.

So it was not lack of technical development which delayed so long the coming of the sound film, or any great technical advance that finally produced it. It was—to speak frankly—the artistic ineptitude of the magnates of Hollywood. The cinema was past its first youth. Its technique had lost its wonder even for the half-civilised races, and more sophisticated patrons were grumbling at the poverty of imagination displayed by those who controlled so wonderful an instrument. Hollywood saw that something had to be done to stimulate a flagging demand; they decided to appeal to the lower rather than to the higher instinct of mankind, to drown criticism in the clamorous excitement of a new 'stunt' rather than to satisfy it by a belated appeal to intelligence. They would introduce a yet cruder realism; they would reunite sound and sight which the cinema had divorced. The public should have the thrill of talking pictures!

They began with gramophone records—sound-on-disc, as it is called. And if technical excellence had been the sole consideration, they might long have kept to them. It is only quite recently that the alternative sound-on-film has equalled and even surpassed the best gramophone record. We must insist on that, because those who do not like sound films must not blame photoelectric cells for their deficiencies. If you think they are worse than silent films—for this is the only question—if you think that the art of Walt Disney is a poor substitute for that of Charlie Chaplin, you must remember that the change might have and probably would have occurred, if photoelectricity had never been heard of. Perhaps we might not have had the 'Home Talkies' with which we are now threatened; but public talkies we should have certainly had. That is important, because we are apt to forget when we are discussing history that the same effect may arise from quite different causes, and that abolishing the immediate cause does not always mean abolishing the actual effect.

However, actually sound-on-disc began soon to be replaced by sound-on-film, and to-day is almost completely obsolete. Sound-on-film means that there is printed on the film, alongside the picture, a strip of transmission varying with the vibration of the recorded sound. Light from the projector—usually a subsidiary projector—passes through this strip and falls on a photoelectric cell, the varying current for which is fed through amplifiers to a loudspeaker The reasons why sound-on-films has replaced sound-on-disc are two. First, that recording sound-on-film is a photographic process ; motion picture engineers knew all about photography, but they did not know about the highly specialised art of making gramophone records. But the second is even more important. When sound-on-disc is used, the record is on two separate objects, which is inconvenient for many purposes ; when sound-on-film is used, it is all on one, and there is no fear of the two parts of the record becoming dissociated in any way.

Here we are going to leave for a moment actual history for imaginary, and point out to you what great and curiously indirect effects might have flowed from small causes. It is the advantage of sound-on-film that the record is a single object. But that is not an unmixed blessing in an *international* industry. The same picture will do in all countries, but not the same sound ; language differences have to be taken into account. Now suppose that the Hollywood magnates had been far-sighted visionaries or even tyrants, consistently intent only on their own advantage—perhaps that is more likely and equally effective ; and suppose they had said ' we are going to have none of this silly Tower of Babel business. If people want to see our films, they've got to learn our language. We'll make it easy for them and use some simplified form of English or perhaps even Esperanto.' Don't you think they might probably have got away with it and imposed upon all the earth an international language ? Remember how the idioms of Hollywood have permeated our speech and how many of us, in a short five years, have become almost bilingual, speaking American but still reading English. Perhaps you are not quite sure whether the consequences would have been good or bad ; but there is no doubt that they would have been extremely important and have had enormous political and social repercussions. The whole history of mankind might have been unforeseeably influenced by some long-neglected laboratory toy exploited at last for some entirely irrational purpose.

Now let us return to fact. There is another aspect of this unexpected development of photoelectricity. Photoelectric cells produced the sound film ; but the sound film also produced photoelectric cells by creating a demand for them. Hitherto cells had been made in ones or twos by laboratory workers ; now they were demanded in thousands ; it became worth the while of large industrial concerns to manufacture them and to apply to the problem their vast experience in similar fields. The emission cells received particular attention, for these had many advantages over conductive cells for talking pictures ; and the problems they presented were similar to those of incandescent lamps and thermionic valves which had been for years the main concern of industrial research organisations. In a very short time the first considerable advance had been made since the days of Elster and Geitel, thirty-five years before ; the sensitivity of emission cells was increased greatly, and sensitivity—the current due to a given amount of light—was still important in spite of our new powers of amplification.

But such improvements alone would not have extended greatly the field of photoelectric applications ; the obstacle to extension was not lack of technical power, but simply ignorance on the part of those who might use it. Once photoelectric cells became the concern of the large electrical

firms, they were brought to the attention of all electricians. Slowly they began to be regarded, not as curiosities arousing the enthusiasm of a few specialists, but as normal tools at the disposal of the normal engineer for any purpose to which they might be adapted. The end of that stage has not quite been reached; there is still a group of enthusiasts whose one idea is to find some use for photoelectricity even when alternative methods are obviously preferable; and another group of the unconverted who regard them as unproved novelties. But the intermediate group is steadily gaining ground; at last originality and sound judgment are at work together. And that—mind you—is largely due to talking films!

Let us then inquire soberly and in the light of our present knowledge, what is the proper field of photoelectricity. The advertiser loves to descant on the marvels of the electric eye; and that phrase, which can hardly have escaped your attention, suggests that the proper function of the photoelectric cell is to replace vision. Now that is quite wrong. The eye may be physiologically the equivalent of a vast assembly of photoelectric cells connected to an inconceivably complicated automatic telephone exchange located in the brain. But any practicable combination of cells and accessories share with the eye only one common power, that of distinguishing light from darkness. The cell lacks altogether the power of the eye to appreciate directly form and colour, and on that appreciation most of the uses of vision depend. On the other hand the cell possesses powers that the eye lacks; it can detect much smaller variations in illumination and much more rapid variations.

The first of these powers makes photoelectric cells valuable *measuring instruments*. That has been realised from the start. Wernher von Siemens made a selenium photometer in 1875; Elster and Geitel studied measurement with great care and insight. (Measurement is a much more complicated matter than most people suppose.) But, except in astronomical observatories, where the great sensitivity of the cell to small amounts of light was valued, photoelectric photometry was not practised seriously before the war. Since then its use has spread at an increasing rate. It is often more convenient than visual observation; its convenience has been enhanced greatly by the appearance of the rectifier photoelectric cell within the last five years. For instance, photographic exposure meters using such cells are now on sale for general use. But the quality on which we want rather to insist is its accuracy. The importance of accurate measurement in industry is not generally understood. Thus, since the usual purpose of light is to enable us to see, it is not immediately obvious why any measuring instrument more accurate than the eye is necessary or desirable. The answer is that variations in quality too small to affect appreciably the finished product provide a most valuable clue to defects in manufacture which, if they are unchecked, will lead to waste. It does not matter much to you whether one lamp that you buy gives one per cent. more or less light than another; but it is by keeping track of such small differences that manufacturers have steadily improved the quality and diminished the cost of lamps by eliminating waste. Here is a function of science that in uniformly beneficial. Even in our mad world, where we try to rectify economic disasters by destroying valuable products such as coffee and rubber, waste—the expenditure of human energy in achieving undesired results—is surely an unmixed evil. The elimination of waste is one of the least spectacular achievements of science, and one of which the general public seldom hear; but it is one of the most useful. Here photoelectric cells have much to their credit.

Another potential advantage of photoelectric over visual measurement

is its speed. This advantage has been realised to some extent ; but the extent has been greatly exaggerated. When photoelectricity is mentioned in the popular press one of the things that always turns up is a machine for sorting cigars and coffee beans according to their colour. That is, of course, very high speed measurement. Now sorting machines of this kind can undoubtedly be made ; a beautiful example made by Mr. Horsfield was shown a little time ago in the Exhibition at the Science Museum. But they are emphatically not yet general ; we have never yet been able to hear of one in regular use. The difficulty is that the qualities that should determine sorting in these cases, although simple enough to the eye, are intricate combinations of form and colour that mislead any less complex instrument. Developments in this direction are quite probable ; but at present it is yet another direction in which enthusiasm has outrun discretion.

The speed of action characteristic of photoelectric cells can be utilised only when little else is demanded. Use of it is made, of course, in sound films ; for the cell has then to follow light vibrating with the frequency of sound, that is to say, thousands of times a second. Even greater demands on it are made in television. Perhaps you have been expecting us to say much on this subject, which is so topical ; but it is not of great interest from our present standpoint ; its implications, so far as they can be foreseen, have long been obvious to all, and are not very different from those of picture telegraphy, which has actually been achieved. The idea of television was in the minds of the earliest inventors ; and, as I have said, they formulated its problems quite correctly. For the last fifteen years at least all the fundamental problems have been solved in principle ; it has been clear that the attainment of television of almost any desired degree of excellence has been simply a question of expense. We must not appear to belittle the work of those who have achieved so much in this field ; if an engineer is one who can do for a shilling what any fool could do for a pound, then they have truly proved themselves engineers. Perhaps the most useful remark we can make is this The long period of delay, while it has been doubtful whether the public would be attracted by such television as can be provided for the price they might be expected to pay, has given us an opportunity of controlling its developments such as rarely occurs. If all inventions were subject to similar delays, the control of the social effects of science would be much easier. As you know, a Committee is at work deciding how, if at all, television is to start. We hope they will not confine their attention to its start. When it starts, and if it succeeds at all, it is sure to develop in directions that we cannot at present foresee. The control of science, if it is to be effective, must be continuous and ever active. Let us hope that this exceptionally favourable chance will not be missed.

The speed of photoelectric cells is also utilised in some other directions. Thus they are widely used in timing races, specially on greyhound tracks. Perhaps this is not an application that will appeal to you ; but after all, if greyhound races are to be timed at all, they may as well be timed rightly. Another possible application in the same direction may appeal to some of you still less. If a speed limit is imposed by the new Road Traffic Act, photoelectric cells might well be used to make it effective. The old system of timing over long distances by fallible constables armed with manual stop-watches is obsolete ; there would be no difficulty to-day in timing a car over a distance of 15 or 20 feet without possibility of human error and with all the accuracy required.

The last class of applications, immensely varied, does not use either of the powers in which the cell surpasses the eye ; it uses merely the common power of distinguishing light from darkness. The only difference is then

that the response of the cell is automatic and does not require the intervention of a human will. Many of these applications were quite feasible in the earliest days of photoelectricity ; for relays, which are a necessary element of the apparatus, were used in telegraphy. But the attention of inventors was so concentrated on the marvellous that they missed the obvious ; the earliest reference we have found to any of these simple applications is well within the present century ; but it is possible that earlier suggestions were made. Serious attempts to exploit these applications only began with the formation of Radiovisor Ltd. in 1928.

Two suggestions that constantly recur are to turn on public lighting when dusk falls and to detect burglars by their passage across a beam of light. But for the first purpose a time switch is really more effective ; and burglars are, alas ! rather more intelligent than inventors imagine. But some later suggestions have proved practicable ; here are a few : The detection of black smoke issuing from a chimney, speeding up an escalator when a passenger steps on it, detecting pin-holes in metal sheet for motor-car radiators, stopping paper-making machinery when the paper tears, counting objects of any kind as they pass down a conveyor, making sure that every packet of cigarettes contains its card, preventing vehicles from attempting to pass under a bridge too low for them, guiding cloth past a knife by which it is to be cut. Photoelectrically all these applications are the same ; the object to be detected either interrupts or releases a beam of light passing across its path ; they differ only in the consequences that result from that interruption or release ; the securing of the necessary consequences is merely a matter of ordinary electrical engineering. There are usually other methods of achieving the same end ; the cell could usually be replaced by a mechanical contact.

These comparatively dull and trifling applications of photoelectricity are of especial interest from the point of view from which we started ; for they are the most likely to produce one of the main evils that is now laid to the charge of science. Here we have a direct replacement of man by the machine ; the replacement sometimes saves waste because machines are less irregular, but its object is usually economic ; the machine is cheaper and more profitable. Of course there is good as well as evil ; to sit in darkness watching for holes in an endless strip of brass is not an ideal way for a lad or girl to spend the working day ; it is tolerable only because the alternative of no work at all, and no pay, is even worse. In dealing with this problem scientific foresight is not required ; the means to replace all forms of drudgery by machine operation already exist ; the future has little new for us here ; the sole question is whether we can devise a better alternative to drudgery and thus justify the use of the means that lie to our hand. That is a political question, concerning which science may provide the facts, but can never provide the decision.

And so our tale ends, very inconclusively and unromantically, as all scientific tales must. For science achieves its purpose only when it becomes so commonplace that it is taken for granted and becomes part of everyday thought and practice. The *ultimate* aim of science is always to be uninteresting. We hope we have not been too scientific.

OPENING OF DISCUSSION

IN SECTION C (GEOLOGY)

ON

UNDERGROUND WATER SUPPLY

BY PROF. W. S. BOULTON.

(*Ordered by the General Committee to be printed in extenso.*)

THE serious drought which has afflicted this country, in common with many others abroad, for more than a year, causing intense anxiety in many quarters as to the sufficiency and proper distribution of our water supplies, may have helped to provoke the present discussion. But, apart from our immediate water shortage in many parts of the country, some of us have long felt that this question of underground water, falling as it does primarily within the domain of the geologist, should interest the Geological Section of the British Association.

The Committee on Inland Water Survey, inaugurated at the York Meeting two years ago, had for its main object the organisation of a water survey of the country, and, although its terms of reference include underground water, I gather from the constitution of the Committee, and from its report issued at the Leicester Meeting last year, that its work will be confined for the most part to surface water, thus coming within the scope of the engineer and the geographer, and to a less extent the geologist. We learn, indeed, from this report that the Council of the Institution of Civil Engineers 'will be prepared, if they are so requested by the British Association, to appoint a Committee to investigate the feasibility of carrying out the objects outlined in the Report.'

On July 19 last, a deputation from the British Association and the Institution of Civil Engineers met the Minister of Health, and invited the Government to give favourable consideration to the institution of a complete and systematic survey of the water resources of the country. We shall await with interest the Government decision.

It would appear likely, however, that such a water survey, if carried out under the auspices of the Ministry of Health or by the Institution of Civil Engineers, will be primarily concerned with surface water, and in any case is likely to leave a wide unexplored field for observation, record and study which can only be adequately undertaken by geologists.

Underground water can be divided for our present purposes into two categories : first, *meteoric* water, which is supplied directly from the rainfall, and percolates from the surface through the rocks ; and second, what has been termed *plutonic*, *magmatic* or *juvenile* water, normally deep-seated and more or less hot, with a notable absence of chlorine, which characterises meteoric water, but with other characteristic constituents like boric acid. With plutonic water we may class the so-called *connate* water, originally stored in sedimentary rocks. I propose to confine this discussion to meteoric water.

In our text-books it is frequently stated that rain water follows one of three courses—it is evaporated and absorbed by vegetation, it runs over the surface to the sea, or it percolates below ground. And this is followed by the statement that the surface run-off is determined by measuring the discharge of rivers. But a little consideration shows that, neglecting the small fraction which may flow directly into the coastal strip, the total river discharge gauged near the river mouths measures the surface run-off, plus the percolation which emerges at the surface in springs and seepages, to find its way into rivers and the sea. So that river discharge, subtracted from rainfall, gives the loss which is evaporated and absorbed by vegetation.

With regard to the surface, the water stored in lakes and reservoirs may be regarded as more or less permanent, but not absolutely stationary, the inflow from surface streams and springs, together with that supplied directly by rain, being balanced by their outflowing streams, and by evaporation from their surfaces.

In like manner the underground storage in the rocks may be thought of as more or less permanent, though not stagnant, the replenishment from percolation balancing the natural outflow in springs and seepages, together with that which may be artificially pumped to the surface. But in the ultimate analysis, it is the replenishment by rainfall of both surface and underground storage which balances the total run-off, plus absorption and evaporation loss.

Since our concern is with underground water, it is evident that it would be of value to determine, if possible, the fraction of the rainfall in any area which replenishes the underground reservoir, and emerges at the surface in natural springs and seepages, or is available for pumped water supplies.

As regards *rainfall*, we are fortunate in having available records all over the country, mainly through the work of the British Rainfall Organisation, which collects, analyses, and publishes every year the gaugings of some 5,000 observers. As some of these records go back for seventy-five years and even longer, we are able to abstract from them, though as yet imperfectly, the long and short cycles of wet and dry years. With more complete records and a better understanding of the incidence, and possibly the causes, of these cycles, we may some day be in a position to anticipate and make provision for these periods of excessive rainfall and drought.

When we turn to the records of *river gaugings*, we have to confess that we in this country have been sadly negligent in the past, and far behind the United States, for example. The Inland Water Survey Committee, already referred to, is seeking to make good this deficiency, but obviously it will take many years of systematic work before the data we so badly need are available.

How then is it possible to estimate the quantity of underground water which is available for use in any area? What fraction of the rainfall normally percolates downwards from the surface to replenish the underground reservoir?

If, in any watershed or basin, we know the total run-off, which includes percolation, then of course this figure, subtracted from the rainfall, will give us the loss by evaporation. And it so happens that in this country this loss, arrived at by difference, is practically the same as the figure we get by measuring the loss from artificially constructed evaporation tanks. But then we do not know the fraction of the total run-off which is due to percolation.

It is the practice of water engineers to assume an evaporation loss, which in this country varies widely. It may be as low as 10 or 11 in. of rainfall in northern hilly districts, and perhaps as high as 18 or 19 in. in the south

of England. The remainder is taken as run-off, of which a certain fraction emerges at the surface after percolating into the ground. This percolation fraction will obviously vary greatly in different districts, according to the permeability of the rocks, the existence of fissures, the nature of the surface, the general topography, and so forth. In practice it is usual to base one's estimate upon experience of the quantities of underground water which can be pumped in a given area without lowering the general water-table.

Percolation Gauges.—A direct and apparently simple method of determining the percolation at any place is to use a Percolation Gauge, such as those designed by Baldwin Lathom at Croydon, or those at Rothamsted. The results obtained from these gauges are useful for agricultural purposes, but for measuring the total fraction of rain which percolates to depth in the rocks they have their limitations. Without entering into detail, it is obvious that because of their shallow depth—5 ft. at most—there must be some evaporation loss after percolation, and their surface cannot be regarded as a true replica of the average natural surface of the district. A more serious defect, in my opinion, is that the permeability of the rocks, apart from joints and fissures, diminishes with depth, for most rocks are more permeable near outcrop than at a depth of, say, one or two hundred feet. The consequence is that some of the percolated water at shallow depths finds ready exit to the surface at low-lying places, without a chance to sink to the main water-table, which may be much deeper.

Very few determinations of the permeability of rocks at depth have been made. I have recently estimated the permeability of some samples of water-bearing sandstones in the Birmingham district, and the results are rather surprising.

In a deep boring through Bunter sandstone, seven sample cores, at depths varying from 300 to 750 ft., were selected for porosity and permeability tests, and it was found that the porosity, or percentage of pore-space, varied from 13·2 per cent. to 30·3 per cent. The permeability, or flow of water in gallons per square foot in 24 hours, varied still more, namely, from 0·05 to 17·4. Although the constant head of water under the conditions of the experiment was here small, viz. 6 in., the results for the different samples are strictly comparable. They serve to show that Bunter sandstones in the same boring may vary greatly in their capacity to transmit water, and therefore to yield their supplies to wells and boreholes.

In another set of experiments on a Keele sandstone, varying from 20 to 40 ft. thick, and underlying impervious marls, samples were taken from cores at a depth of about 100 ft. in many different boreholes, and also from the same sandstone near outcrop. Here, again, the porosities varied from 3·58 per cent. to 20·3 per cent., and the permeability in the direction of bedding, i.e. perpendicular to the cores, was astonishingly small, but distinctly higher near outcrop. In the latter experiments I had the means of estimating almost exactly the amount of water which this bed of sandstone was transmitting from a reservoir, and the conclusion was inevitable that practically all the water passing through the sandstone was moving in joints and fissures. And yet the rock is a medium-grained sandstone with fair porosity, and would be described as a water-bearing rock.

That porosity has no necessary relation to permeability is well known. Chalk may have a porosity of nearly 50 per cent., and yet wells and borings in it may yield no water unless there are fissures or bands of flint. This is also true to some extent of other porous rocks, such as sandstone.

It would be all to the good to have a large number of such measurements of porosity and permeability of samples taken from known water-bearing strata at different depths, and not to rely on a figure, taken maybe from a

text-book, and based upon a single determination, and without reference to the position from which the sample was taken.

But it is clear that systematic observation and experiment on the larger scale are required if we wish to estimate our underground water resources.

There is much misconception of this problem in the mind of the general public, not to mention those whose business it is to recover and utilise underground water supplies. In recent months I have read numerous letters and special articles in the public press urging that we have underground in this country an inexhaustible supply of water. Instances are cited where a powerful spring or a large pumping station is yielding several million gallons of water a day, and, from a few such isolated cases in different parts of the country, it is argued that, if you bore down deep enough almost anywhere, there is the water in similar amounts asking to be pumped to the surface.

I recently heard a very able and suggestive paper read before water engineers, in which the author advocated the extraction of underground water from comparatively shallow wells and boreholes in rural areas, utilising the power from the electric grid, in preference to the distribution of water from a regional source. 'The vast extent of underground storage' was a phrase used.

Two important things must be borne in mind in this connection. First, if the underground water storage is drawn upon, as in times of prolonged drought, in excess of percolation from rainfall—if, in other words, the wells are continuously overpumped—it necessarily follows that the water-table is thereby continuously lowered while this excess lasts, thus depleting or drying up the shallower wells, and increasing the depth and cost of pumping the deeper wells. Not only so, but surface supplies from springs and streams are also depleted, to the detriment of lowland surface water supplies, canals, fisheries, agriculture, power stations, etc. Some folk have suggested that a national or regional scheme should be adopted, whereby the underground reservoirs are left practically intact, and their natural overflow allowed to feed surface springs and streams, and that the flood waters in upland regions collected in large reservoirs could be distributed by a widely spread system of pipe-lines, or 'grid,' and so give an adequate supply to the whole community. As regards quantity, such a scheme does not seem ambitious, seeing that it has been calculated that the present domestic supply in the British Isles does not amount to more than about 1 per cent. of the total rainfall. But I must not be tempted to pursue this further, or even to outline the difficulties as to cost, vested interests, and so forth, inherent in such a scheme. It is a matter of public policy and does not directly concern us here and now.

It is well known that even in times of normal rainfall there are areas in and around some of our big cities, like London, where the underground water level is slowly and continuously falling, due to overpumping. One of the questions which call for investigation is that of these overpumped areas. The widespread impervious mackintosh of streets and houses aggravates the problem, by diminishing the natural percolation.

In the second place, we geologists know well enough that large stretches of country are underlain by impervious and non-water-bearing rocks, such as the Keuper Marls of the English Midlands, and the Jurassic clay belts of the south and east of England. Borings through this impervious cover to depths, it may be, of many hundreds of feet may fail to tap water of potable quality.

The underground storage is *not* inexhaustible, and there are many areas

where it is hopeless to expect a fair supply of potable water at moderate depths.

I suggest that what is urgently needed is that regions with well-defined physiographical, formational or tectonic limits should be selected for hydrological study. For water supply purposes it has generally been the custom to choose county boundaries as the defined limits, as in the case of the *Water Supply Memoirs* of the Geological Survey. For administrative purposes there is good reason for adopting these county boundaries, especially now that the county councils have some control in financing and administering rural areas in the matter of water supply. But for the purposes we are now considering it is preferable to adopt natural unit areas, such as a river basin or watershed, or a tectonic structure like the Hampshire Basin, or a formation unit like the Chalk or the Bunter, or, perhaps better still, a specific water-bearing formation in some watershed or unit geological structure.

The quantities of underground water which are pumped for long and short periods in the whole areas so defined should be estimated, and the rainfall statistics of the region recorded for the same periods, together with the surface conditions, including topography, cultural features, built-up areas, and so forth. In addition to quantities of water pumped at individual stations, we want details of static and pumping levels, and the effect of pumping at any one station upon neighbouring wells, streams, etc.

In such a defined region continuous records of water levels in wells should be kept, and if possible springs and streams gauged systematically. During the progress of such work it would be possible to express graphically the hydrological conditions. But I would stress the necessity in all such correlations of taking practically simultaneous records—for example, of the water-table. When we realise that the well levels in the Chalk country, for instance, may vary seasonally as much as 150 ft. or even more, we can understand the necessity of correlating data and expressing the facts as they are at a given time.

I am well aware that useful work of this nature has already been done in a few isolated areas, and I gratefully pay tribute to such valuable contributions as those of Mr. D. Halton Thomson on the hydrological conditions of the Chalk of West Sussex, and the more general hydro-geology of the Chalk of England by Mr. R. C. S. Walters, and others. Their work should be an incentive to geologists interested in this branch of our science. I am convinced that the systematic collection and correlation of hydro-geological data at present available, together with new ascertainable data, would prove of the greatest value, both as a contribution to pure science and for the full and proper utilisation of our water resources. Work of this nature could best be done by geologists with an intimate knowledge of the areas selected for study.

In the past many records have been published which are more than imperfect and faulty—they are positively misleading. It is not to be expected that a boring foreman or well-sinker should correctly name the strata passed through ; it is not always insisted that cores are properly laid out and marked ; water levels are stated without surety that they are true rest levels, and quantities given as pumped may be the initial yield, and not the constant yield after equilibrium has been established.

The *composition* of underground water is a subject of sufficient importance to warrant separate treatment. Apart from organic purity, which is essential in all potable water supplies, there are limits of mineral content beyond which water is unfit for general domestic or industrial use. I know of little work so far done in preparing graphs and charts showing the geographical

or geological distribution of waters of different 'hardness.' And there are many cases of waters of abnormal composition which, if recorded and investigated, might yield results of scientific or industrial value.

Organisation of Research.—What should be the aim in organising research in our underground water supplies, in collecting existing data, correlating them, and making them available for the scientific inquirer, and for engineers and others with a view to their maximum public utility ?

The Ministry of Health, in association with engineering institutions, are at the present time alive to the necessity of some action. Regional Advisory Committees have already been formed in some parts of the country to collect information as to water resources and requirements in their respective areas. But these committees are devoid of statutory authority, they are not financed, and for the time being they can do little more than to explore the ground to be dealt with later. Moreover, they are dealing almost exclusively with surface supplies.

Perhaps the ideal plan would be for a central or Government Department of Hydrology, including hydro-geology, to undertake, apart from administrative duties, some of the research work I have outlined here. The Department of Scientific and Industrial Research at once suggests itself in this connection. Others may think that the Geological Survey is the appropriate body. In the United States the Geological Survey has always included water supply and irrigation as an important part of its functions, and its water supply publications have been of great service to engineers, agriculturists and geologists, not only in the United States, but all over the world. But if the Geological Survey of Great Britain undertook this work it would mean a considerable reorganisation and addition to the staff, and a largely increased grant from Government. For many years past the Geological Survey has published county *Water Supply Memoirs*—some twenty-six up to the present time—which have proved of great service to engineers, public authorities and others. We owe a debt of gratitude to the late Mr. Whitaker for his enthusiasm and industry in compiling many of these memoirs.

At the same time it must be admitted that the material in these publications, with some notable exceptions, is mainly a compilation of existing records from many sources, some of them ancient and unchecked, and necessarily incomplete. The Geological Survey has also in its possession many thousands of records of wells and borings, many of which can be consulted by those interested in water questions.

Again, a mass of hydrological data has been collected by the Ministry of Health, partly with a view to some possible future scheme of co-ordinating or grouping water authorities into water boards. This material is only available for official purposes, and in any case it would require, I imagine, much sifting and interpreting before it could be made available for further scientific inquiry or public use. Nor, so far as I know, does it include the kind of observation, recording and research on underground water to which I have referred.

The question I want now to put before you is this : What can we do, what can this Section of the Association do, to stimulate investigation along some of the lines I have indicated ? Can we encourage individuals or groups, with the requisite geological knowledge and enthusiasm, to collect and record existing data relating to underground water supply, and where possible to extend these data, and to interpret and publish the results ? Is this the time to form a Committee with objects ancillary to, but distinct from, those of the recently formed Committee on Inland Water Survey ?

The idea is not altogether novel, for Committees of the British Association,

inaugurated more than twenty years ago, did sound pioneer work in this field. A Committee on underground circulation in the New Red Sandstone and Permian was started in 1874, the scope of which was extended in 1881 to the permeable formations of England and Wales. Dr. Howarth, the Secretary of the Association, has kindly supplied me with a note on the work of this Committee, as published in the Annual Reports of the Association down to 1895, when the Committee lapsed. The moving spirits in this work were De Rance and Whitaker, and a great mass of information was collected during those twenty years. Towards the end of that period, De Rance made a digest of all the previous reports, but up to now the whereabouts of this summary has not been traced. Some of the records of this Committee have been subsequently incorporated in the *Water Supply Memoirs* of the Geological Survey, and others extensively used by water authorities and experts.

Another Committee on the 'movements of underground waters in north-west Yorkshire' worked in conjunction with the Yorkshire Geological and Polytechnic Society, and published its last report in 1905.

Whatever be the outcome of the conferences now being held by various engineering societies and the Ministry, prompted at the moment by the shortage of water due to the drought, there will remain the urgent need of investigation and patient research on underground water, and the accumulation of properly sifted data and records, published in such a form and with such authority that they can be utilised for further inquiry, and made available ultimately for the public good, whether through regional bodies or a central authority. Are we in a position to help forward this work ?

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

The titles of discussions, or the names of readers of papers in the Sections (pp. 269–405), as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting.

Section A.

Bragg, Prof. W. L.—Cf. *Proc. Roy. Soc.*, A, **145** (1934).

Howe, Prof. G. W. O.—*Electrician*, **113**, p. 329, Sept. 14 (1934).

Howell, H. G.—*Proc. Univ. Durham Phil. Soc.*, **9**, pt. 3.

McCrea, Dr. W. H.—Expected to appear in *Zeitschr. für Astrophys.*

Naismith, R.—Cf. *Nature*, **132**, p. 340 (1933) ; *ibid.*, **133**, pp. 57, 66 (1934) ; paper to appear in *Proc. Roy. Soc.*

Ratcliffe, J. A.—Cf. *Proc. Phys. Soc.*, **46**, p. 107 (1934).

Thomson, Prof. G. P.—Cf. *Phil. Mag.*, Ser. 7, **16**, p. 961, Nov. (1933) ; *Proc. Roy. Soc.*, A, **140** (1933).

Young, C.—*Times*, Sept. 13 (1934) ; cf. *Proc. Jun. Inst. Engs.*, **42**, pt. 11, Aug. (1932).

Department A*.

Marr, Dr. W. L.—Cf. *Proc. Camb. Phil. Soc.*, **21**, 599 (1923) ; *Journ. Lond. Math. Soc.*, **1**, 86–93 (1926) ; *ibid.*, **5**, 193–195 (1930).

Department A†.

Williams, E. G.—*Pubns. of Astron. Soc. of Pacific*, Oct. (1934) ; to appear in extended form in *Astrophys. Journ.* (1935) ; cf. *Ann. Solar Phys. Observ., Cambridge*, **2**, pt. 2 (1932).

Joint Sessions on Technical Physics, AG.

A general report of the transactions in these sessions appeared in *Engineering*, **138**, 3589, Oct. 26 (1934).

Angus, T. C.—Expected to appear in *Journ. Textile Inst.*, Nov. or Dec. (1934).

Crowden, G. P.—*Engineering*, **138**, p. 395, Oct. 12 (1934).

Davies, L. J.—On 'Road Illumination,' *Electrician*, p. 390, Sept. 28 (1934).

Douglas, A. H.—*Engineering*, **138**, 3591, p. 513, Nov. 9 (1934).

Dufton, A. F.—Cf. *Building Res. Tech. Paper*, no. 13 (1932) ; *Journ. Hygiene*, **33**, 3, p. 349 (1933) ; *ibid.*, **33**, 4, p. 474 (1933) ; *Journ. Inst. Heating & Ventilating Engs.*, **2**, 18, p. 256 (1934).

Fishenden, Dr. Margaret.—*Engineering*, **138**, 3590, p. 479, Nov. 2 (1934).

Herbert, E. G.—*Machinist*, Sept. 22 (1934) ; *Engineer*, **158**, 4108, p. 332, Oct. 5 (1934) ; *Metallurgia*, Sept. (1934) ; to appear in *Engineering*, cf. *Proc. Roy. Soc.*, A, **130**, p. 514 (1931) ; *Metallurgia*, **4**, pp. 9 and 47 (1931) ; *ibid.*, **5**, p. 13 (1931-2) ; *ibid.*, **6**, p. 120 (1932) ; *ibid.*, Nov. (1933) ; *Proc. Inst. Mech. Eng.*, **124**, p. 645.

Johansen, F. C.—*Engineering*, **138**, 3585, p. 330, Sept. 28 (1934).

Knight, H. de B.—*Electrician*, p. 390, Sept. 28 (1934) ; *Engineer*, **158**, 4108, p. 332, Oct. 5 (1934).

Lloyd-Evans, B.—*Engineer*, **158**, 4108, p. 332, Oct. 5 (1934) ; to appear in *Engineering*.

Marsh, Dr. M. C.—Abridged version in *Yorks. Post*, Sept. 14 (1934) ; cf. *Proc. Phys. Soc.*, **42**, p. 570 (1930) ; *ibid.*, **45**, p. 414 (1933).

Maxted, P.—*Electrician*, p. 390, Sept. 28 (1934).

Ruff, H. R.—*Electrician*, p. 390, Sept. 28 (1934).

Saunders, O. A.—*Engineering*, **138**, 3589, pp. 436, 446, Oct. 26 (1934).

Small, Dr. J.—To appear in *Phil. Mag.*

Watts, S. S.—*Engineer*, **158**, 4108, p. 332, Oct. 5 (1934) ; to appear in *Engineering*.

Whipple, R. S.—*Electrician*, p. 360, Sept. 21 (1934) ; summary in *Engineering*, **138**, 3592, p. 541, Nov. 16 (1934).

Section B.

Ascorbic acid (vitamin C), discussion.—*Nature*, **134**, 3393, p. 724, Nov. 10 (1934).

Chemistry of milk, discussion.—*Chem. Age*, p. 230 (Sept. 15) ; *Nature*, **134**, 3391, p. 669, Oct. 27 (1934).

Allsopp, Dr. C. B.—Expected to form pt. VIII of a series in *Proc. Roy. Soc.* of which other parts are :—I—**133**, 26 (1931) ; II—**133**, 36 (1931) ; III—**133**, 48 (1931) ; IV—**143**, 618 (1934) ; V—**146**, 300 (1934) ; VI—**146**, 313 (1934).

Boys, S. F.—Cf. *Proc. Roy. Soc.*, A, **144**, pp. 655, 675 (1934).

Cox, E. G.—Expected to appear in extended form in *Journ. Chem. Soc.* ; cf. *Nature*, Aug. 6 (1932) ; *ibid.*, 888 (1932) ; *ibid.*, **131**, 402.

Davies, Dr. W. L.—Cf. *Analyst*, **57**, 79 (1932) ; *Journ. Dairy Res.*, **4**, 142 (1933) ; *ibid.*, **4**, 273 (1933) ; *Nature*, **134**, 3391, p. 669, Oct. 27 (1934).

de Laszlo, Dr. H.—Cf. *Proc. Roy. Soc.*, A, **146**, 662 ; *Comptes Rendues de l'Acad. des Sciences*, **198**, 2235 ; *Nature*, **134**, 63.

Eastwood, E.—To appear in *Proc. Roy. Soc.* ; cf. *Nature*, **133**, 908 (1934).

Haworth, Prof. W. N.—*Nature*, **134**, 3393, p. 724, Nov. 10 (1934); cf. *Nature*, 24 (1933); *Journ. Soc. Chem. Ind.*, **52**, pp. 482 and 645 (1933); *Journ. Chem. Soc.*, 1419 (1933); *ibid.*, 62 (1934); *Helv. Chim. Acta*, **17**, 520 (1934); *Journ. Chem. Soc.*, 1155 (1934); *ibid.*, 1192 (1934).

Hilditch, Prof. T. P.—*Chem. Age*, p. 230, Sept. 15; cf. *Analyst*, **54**, 75 (1929); *Biochem. Journ.*, **24**, 1098 (1930); *ibid.*, **25**, 507 (1931); *ibid.*, **27**, 889 (1933); *ibid.*, **28**, 779 (1934); *Nature*, **134**, 3391, p. 670, Oct. 27 (1934).

Hirst, Dr. E. L.—Cf. *Nature*, 888 (1932); *Journ. Soc. Chem. Ind.*, **52**, 221 (1933); *Nature*, **131**, 402; *ibid.*, **131**, p. 617 (1933); *ibid.*, Aug. 6 (1932); *Journ. Soc. Chem. Ind.*, **52**, p. 645 (1933); *Journ. Chem. Soc.*, 1270 (1933); *Biochem. Journ.*, **27**, 4, p. 1271 (1933); *Journ. Chem. Soc.*, 1419 (1933); *ibid.*, 1564 (1933); *ibid.*, 62 (1934); *Helv. Chim. Acta*, **17**, 520 (1934); *Journ. Chem. Soc.*, 1155 (1934); *ibid.*, 1192 (1934); *ibid.*, 1556 (1934); *Nature*, **134**, 3393, p. 724, Nov. 10 (1934).

Kay, Prof. H. D.—*Nature*, **134**, 3391, p. 669. Oct. 27 (1934).

Kon, Dr. S. K.—*Nature*, **134**, 3391, p. 670, Oct. 27 (1934); expected to be published *in extenso* in near future; cf. *Biochem. Journ.*, **27**, 1302 (1933); *ibid.*, **28**, 111 (1934); *ibid.*, **28**, 121 (1934); *Journ. Soc. Chem. Indust.*, **52**, 844 (1933); *Biochem. Journ.*, **27**, 1189 (1933); *Nature*, **132**, 64 (1933); *ibid.*, **132**, 446 (1933); *ibid.*, **134**, 536 (1934); *Ann. Reports, Nat. Inst. Res. Dairying* (1932 and 1933); further papers to appear in *Biochem. Journ.*

Linderstrøm-Lang, Dr. K.—*Nature*, **134**, 3391, p. 669, Oct. 27 (1934); cf. *Compt. Rend. du Lab. Carlsberg*, **16**, 1 (1925); *Zeitschr. physiol. Chem.*, **176**, 76 (1928); *Compt. Rend. du Lab. Carlsberg*, **17**, 9 (1929); *ibid.*, **19**, 10 (1933); *Zeitschr. physiol. Chem.*, **206**, 85 (1932).

Reichstein, Dr. T.—*Nature*, **134**, 3393, p. 724, Nov. 10 (1934); cf. *Nature*, **132**, 280 (1933); *Helv. Chim. Acta*, **16**, 561 (1933); *ibid.*, **16**, 1019 (1933); *ibid.*, **17**, 311 (1934); *ibid.*, **17**, 510 (1934); *ibid.*, **17**, 753 (1934); *ibid.*, **17**, 996 (1934); *ibid.*, **17**, 1003 (1934).

Snow, Dr. C. P.—To appear in *Proc. Roy. Soc.*; cf. *Nature*, **133**, 908 (1934).

Sutherland, G. B. B. M.—Cf. *Nature*, **134**, 3394, p. 775, Nov. 17 (1934).

Szent-Györgyi, Prof. A.—*Nature*, **134**, 3393, p. 724, Nov. 10 (1934); cf. *ibid.*, 24 (1933).

Tocher, Dr. J. F.—*Nature*, **134**, 3391, p. 669, Oct. 27 (1934).

Section C.

Moinian and Dalradian formations, discussion.—To appear in abridged form in *Nature*.

Underground water supply, discussion.—*Nature*, **134**, 3391, p. 652, Oct. 27 (1934).

Benson, Prof. W. N.—On 'Devonian rocks of Australia,' to appear in extended form in Sir Edgeworth David's 'Geology of Australian Commonwealth'; cf. *Records Geol. Survey New S. Wales*, **10**, p. 83 (1922).

On 'Ordovician rocks of New Zealand,' expected to appear in *Trans. Roy. Soc., New Zealand*; cf. *Trans. N. Zealand Inst.*, **63**, p. 400 (1933).

Bisset, C. B.—Cf. *Trans. Edin. Geol. Soc.*, **13**, p. 72 (1934).

Bremner, Dr. A.—*Trans. Edin. Geol. Soc.*, **13**, pt. 1, p. 17 (1934).

Buchan, Dr. S.—On 'Aberdeenshire granites,' cf. *Trans. Edin. Geol. Soc.*, **13,** p. 72 (1934).

On 'Peterhead and Cairngall granites,' cf. *Trans. Edin. Geol. Soc.*, **12,** p. 323 (1932).

Campbell, Dr. R.—*Trans. Edin. Geol. Soc.*, **13,** p. 176 (1934).

Gibb, Prof. A. W.—*Aberdeen Press & Journ.*, Sept. 7 (1934).

Imlay, Miss J. E.—Cf. *Trans. Edin. Geol. Soc.*, **13,** p. 72 (1934).

Knight, Dr. B. H.—*Quarry and Roadmaking*, Oct. (1934) ; in extended form in *Quarry Managers' Journ.*, Oct. (1934) ; cf. *Journ. Inst. Municipal and County Engs.*, Jan. (1927) ; *ibid.*, Jan. (1934) ; *Surveyor*, Aug. (1933) ; *Journ. Inst. San. Engs.*, Nov. (1933).

Oakley, K. P.—*Proc. Roy. Soc.*, B, **116,** p. 296 (1934).

Read, Prof. H. H.—*Geol. Mag.*, p. 302 (1934) ; to appear in abridged form in *Nature.*

Robbie, J. A.—Cf. *Trans. Edin. Geol. Soc.*, **13,** p. 72 (1934).

Robertson, Dr. I. M.—*Trans. Edin. Geol. Soc.*, **13,** p. 176 (1934).

Scourfield, D. J.—Cf. *Phil. Trans.*, B, **214,** p. 153 (1926).

von Eckermann, Prof. H.—*Geologiska Föreningens Förhandlingar*, **56.**

Section D.

Inheritance of productivity, discussion.—To appear in *Empire Journ. Exp. Agric.*

Cameron, Dr. A. E.—*Aberdeen Press & Journ.*, Sept. 6 (1934) ; cf. *Bull. Ent. Res.*, **17,** p. 1 (1926) ; *Nature*, **126,** p. 601 (1930) ; *ibid.*, **130,** p. 94 (1932) ; *Trans. Roy. Soc. Edin.*, **58,** pt. 1, p. 211 (1934).

Fritsch, Prof. F. E.—Cf. *Journ. Ecology*, **19,** p. 244 (1931).

Greenwood, Dr. A. W.—To appear in *Empire Journ. Exp. Agric.*

Hammond, J.—To appear in *Empire Journ. Exp. Agric.* ; cf. 'Growth and Development of Mutton Qualities in the Sheep' (Hammond and Appleton) Edinburgh (1932).

Hardy, Prof. A. C.—Cf. 'Plankton of South Georgia Whaling Grounds,' pt. 5, *Discovery Reports*, **10.**

Lush, Dr. J. L.—To appear in *Empire Journ. Exp. Agric.*

MacLagan, Dr. D. S.—Expected to appear in *Journ. Animal Ecol.*

Nichols, Dr. J. E.—To appear in *Empire Journ. Exp. Agric.*

Pentelow, F. T. K.—Cf. *Journ. Animal Ecol.*, **1,** 2, Nov. (1932) ; 'Survey of R. Tees' (Technical Paper of Water Polln. Res. Bd.).

Raitt, Dr. D. S.—*Fishing News*, Sept. 7 (1934) ; summary in *Aberdeen Press & Journ.*, p. 5, Sept. 7 (1934) ; cf. *Fisheries of Scot., Sci. Invest., no.* 1 (1932).

Reichensperger, Prof. Dr. A.—Expected to appear in *Zeitschr. für wissensch. Zoologie.*

Sandon, Dr. H.—Cf. *Nature*, **133,** p. 761, May 19 (1934).

Smith, A. D. Buchanan.—*Scottish Farmer*, p. 1379, Oct. 13 (1934); *North Brit. Agriculturalist*, Sept. 13 (1934); to appear in *Empire Journ. Exp. Agric.*

Versluys, Prof. J.—*Nature*, **134**, 3392, p. 706, Nov. 3 (1934).

Wood, Dr. H.—*Aberdeen Press & Journ.*, p. 5, Sept. 7 (1934); *Fishing News*, p. 7, Sept. 8 (1934); *ibid.*, Sept. 10 (1934).

Zuckerman, Dr. S.—Expected to appear in *Science Progress* or *Character and Personality.*

Section E.

Benson, Prof. W. N.—To be embodied in memoir yet to be published.

Crowe, P. R.—May appear in *Geog. Review* (New York); cf. *Scot. Geog. Mag.*, March (1933).

Darby, Dr. H. C.—Cf. *Scot. Geog. Mag.*, **49**, p. 323, Nov. (1933).

Fogg, W.—To appear in *Scot. Geog. Mag.*; cf. *Geography*, **17**, (1932).

Geddes, Dr. A.—Cf. *Geography*, **15**, pt. 3, Sept. (1929); 'Au Pays de Tagore' (Geddes, Paris, 1927).

Smailes, A. E.—May appear in *Geography.*

Snodgrass, Dr. Catherine P.—Cf. *Scot. Geog. Mag.*, **48**, Nov. (1932); *ibid.*, **49**, Jan. (1933).

Taylor, Prof. E. G. R.—*Lecture Recorder*, **4**, 3, p. 64, Oct. (1934).

Section F.

Economic planning, discussion.—Summary in *Nature*, **134**, 3387, p. 503, Sept. 29 (1934).

Bruck, Prof. W. F.—*Nature*, **134**, 3387, p. 503, Sept. 29 (1934); *Times*, Sept. 10 (1934); cf. 'Road to Planned Economy' (Bruck), O.U. Press (1934).

Gray, Prof. A.—*Nature*, **134**, 3387, p. 503, Sept. 29 (1934).

Hamilton, Dr. H.—*Aberdeen Press & Journ.*, p. 5, Sept. 7 (1934).

Macgregor, Prof. D. H.—*Nature*, **134**, 3387, p. 503, Sept. 29 (1934).

Rowson, S.—*Journ. Roy. Statist. Soc.*, **97**, pt. 4 (1934).

Stamp, Sir J. C.—*Nature*, **134**, 3387, p. 503, Sept. 29 (1934).

Department F*.

Experimental method in industrial relations, discussion.—*Nature*, **134**, 3392, p. 707, Nov. 3 (1934).

Dent, A. G. H.—To appear in *Accountant*; to appear in abridged form in *Industry Illustrated.*

Dubreuil, H.—*Labour Management*, Nov. (1934); *Industry Illustrated*, Dec. (1934); in summary in *Nature*, **134**, 3392, p. 707, Nov. 3 (1934); *Lecture Recorder*, **4**, 3, p. 68, Oct. (1934).

Hall, N. F.—*Industry Illustrated*, Nov. (1934); *Nature*, **134**, 3389, p. 579, Oct. 13 (1934).

Lindsay, K.—*Industry Illustrated*, Oct. (1934).

Mackay, R. J.—*Industry Illustrated*, Dec. (1934) ; in summary in *Nature*, **134**, 3392, p. 707, Nov. 3 (1934).

Meyenberg, Prof. F.—*Nature*, **134**, 3392, p. 707, Nov. 3 (1934).

Stamp, Sir Josiah C.—*Industry Illustrated*, Oct. (1934) ; *Colliery Guardian*, p. 505, Sept. 14 (1934).

Wilson, Garnet.—*Scot. Educ. Journ.*, p. 1169, Sept. 14 (1934).

Section G.

A general report of the transactions of this section, together with full reports of individual papers as noted below, appeared in *Engineering*, **134**, 3582, Sept. 7 (1934), *et seqq*.

Reduction of noise, discussion.—*Engineering*, **138**, 3584, pp. 310, 314, 316, Sept. 21 (1934) ; *ibid.*, **138**, 3589, p. 451, Oct. 26 (1934) ; in summary in *Nature*, **134**, 3390, p. 663, Oct. 20 (1934) ; *Engineer*, **158**, 4106, p. 278, Sept. 21 (1934).

Abel, J.—*Engineering*, **138**, 3584, pp. 310 and 314, Sept. 21 (1934).

Allen, R. W.—*Engineering*, **138**, 3587, p. 398, Oct. 12 (1934) ; *Engineer*, **158**, 4106, p. 277, Sept. 21 (1934).

Anderson, F. S.—*Quarry Managers' Journ.*, Oct. (1934) ; *Monumental-Architect. Stone Journ.*, Oct. (1934) ; summary in *Engineering*, Sept. 14 (1934) ; *Engineer*, **158**, 4105, p. 257, Sept. 14 (1934).

Cave-Browne-Cave, Wing-Cmdr. T. R.—*Engineering*, **138**, 3584, pp. 310 and 316, Sept. 21 (1934) ; *Nature*, **134**, 3390, p. 633, Oct. 20 (1934) ; *Engineer*, **158**, 4106, p. 279, Sept. 21 (1934).

Davis, Dr. A. H.—*Nature*, **134**, 3390, Oct. 20 (1934) ; *Engineering*, **138**, 3584, p. 310, Sept. 21 (1934), and subsequently ; *Engineer*, **158**, 4106, p. 279, Sept. 21 (1934) ; cf. chap. 15, ' Modern Acoustics ' (Bell & Sons, 1934) ; *Roy. Aeronaut. Soc. Reprint, no.* 59 ; *Journ. Phys. Soc.*, p. 82 (1931) ; *Nature*, **125**, p. 48 (1930).

Duguid, J.—*Engineering*, **138**, 3584, pp. 310 and 314, Sept. 21 (1934).

Evans, Dr. R. H.—*Engineer*, **158**, 4108, p. 331, Oct. 5 (1931).

Fowler, Sir H.—*Engineering*, **138**, 3584, p. 310, Sept. 21 (1934) ; *Engineer*, **158**, 4106, p. 278, Sept. 21 (1934).

Haigh, Prof. B. P.—*Engineer*, **158**, 4108, p. 330, Oct. 5 (1934) ; *Engineering*, **138**, 3586, p. 364, Oct. 5 (1934) ; *ibid.*, **138**, 3590, p. 461, Nov. 2 (1934) and subsequently ; cf. report of B.A. Committee on Stresses in Overstrained Materials (1932).

Halcrow, W. T.—*Engineering*, **138**, 3583, p. 288, Sept. 14 (1934) ; *Electrician*, p. 359, Sept. 21 (1934) ; *Water & Water Eng.*, Nov. (1934) ; in part in *Engineer*, **158**, 4105, p. 256, Sept. 14 (1934) ; cf. ' Scottish Water Powers ' (paper to Barcelona meeting World Power Conf., 1929) ; ' Water Power Developments in Gt. Brit. & Ireland ' (paper to World Eng. Cong., Tokyo, 1930) ; ' Water Power Resources of Brit. Isles,' *Journ. C.U. Eng. & Aeronaut. Soc.*, 1932.

Hallam, H.—*Engineer*, **158**, 4108, p. 331, Oct. 5 (1934) ; to appear in *Engineering*.

Henderson, Sir J. B.—*Engineering*, **138**, 3585, pp. 335 and 337, Sept. 28 (1934) ; *Engineer*, **158**, 4107, p. 307, Sept. 28 (1934).

Lander, Prof. C. H.—*Engineering*, **138**, 3586, p. 369, Oct. 5 (1934) ; *ibid.* **138**, 3588, p. 423, Oct. 19 (1934) ; *Engineer*, **158**, 4106, p. 269, Sept. 21 (1934).

McClean, Capt. W. N.—*Engineering*, **138**, 3585, pp. 336 and 338, Sept. 28 (1934) ; *Engineer*, **158**, 4107, p. 308, Sept. 28 (1934) ; *Water & Water Eng.*, Nov. (1934) ; cf. *Trans. Inst. Water Engs.*, **32** (1927) ; *ibid.*, **38** (1933) ; *Geog. Journ.*, **76**, July (1930) ; ' Quart. Reports and Records of River Flow, Rivers Garry and Moriston, 1929–31 ' (*River Flow Records*, Parliament Mansions, S.W. 1).

Medd, R. T.—*Engineering*, **138**, 3586, p. 365, Oct. 5 (1934) ; *Engineer*, **158**, 4108, p. 331, Oct. 5 (1934).

Smith, Dr. E. W.—*Engineering*, **138**, 3586, p. 369, Oct. 5 (1934) ; *ibid.*, **138**, 3588, p. 423, Oct. 19 (1934) ; *Engineer*, **158**, 4106, p. 269, Sept. 21 (1934).

Southwell, Prof. R. V.—*Engineer*, **158**, 4108, p. 331, Oct. 5 (1934) ; to appear in *Engineering*.

Thomlinson, J.—*Engineer*, **158**, 4108, p. 331, Oct. 5 (1934).

Turner, E. O.—*Engineering*, **138**, 3584, p. 310, Sept. 21 (1934) ; *ibid.*, **138**, 3589, p. 451, Oct. 26 (1934) ; *Nature*, **134**, 3390, p. 633, Oct. 20 (1934) ; *Engineer*, **158**, 4106, p. 279, Sept. 21 (1934).

Section H.

Callander, Dr. J. G.—*Deeside Field*, no. 6 (1934).

Childe, Prof. V. Gordon.—To appear in extended form in ' Prehistory of Scotland ' (Childe), Kegan Paul (1935).

Curle, A. O.—Cf. *Proc. Soc. Antiquaries of Scotland.*

Driberg, J. H.—To appear in extended form in *Journ. African Soc.*

Earthy, Miss E. D.—Cf. ' VaLenge Women ' (Earthy), O.U.P. (1933) ; *Man.*, Oct. (1934).

Hasluck, Mrs. M. M.—To appear in extended form in *Man* (mid-1935).

Hill, Prof. W. C. O.—Cf. *Nature*, Dec. (1932). Further detailed accounts expected to appear in *Ceylon Journ. Science.*

Keiller, A.—Reprinted by Morven Inst. Archæol. Res. (1934).

MacCulloch, Rev. Canon J. A.—In summary in *Lecture Recorder*, **4**, 4, p. 90, Nov. (1934) ; expected to be embodied in book yet to be published ; cf. ' Medieval Faith and Fable ' (MacCulloch), Harrap (1932) ; *Folk-Lore*, **32**, 227.

Raglan, Rt. Hon. Lord.—*S. Wales Argus*, Sept. 10 (1934).

Scott, Rev. Dr. A. B.—Cf. ' Rise and Relations of Church of Scotland ' (Scott), Andrew Elliot, Edin. ; ' Pictish Nation, People and Church ' (Scott), Foulis, Edin.

Tocher, Dr. J. F.—*Aberdeen Press & Journ.*, p. 4, Sept. 8 (1934).

Section I.

Food preservation, symposium.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

Nutrition in relation to disease, discussion.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

Physiology and pathology of blood, discussion.—*Nature*, **134**, 3392, p. 705, Nov. 3 (1934).

Adams, T. W.—Expected to appear in *Guy's Hosp. Reports* and in book form; cf. *Journ. Physiol. Soc.*, **77**.

Barcroft, Prof. J.—*Nature*, **134**, 3392, p. 705, Nov. 3 (1934).

Cowell, Prof. S. J.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

Davidson, Prof. L. S. P.—*Nature*, **134**, 3392, p. 705, Nov. 3 (1934).

Easterfield, T. H.—Cf. *Journ. Agric. Sci.*, **19**, pt. 3, July 22 (1929).

Edridge-Green, Dr. F. W.—Cf. ' Physiology of Vision ' (Edridge-Green, 1920); ' Science and Pseudo-Science ' (Edridge-Green, 1933); *Post-Grad. Med. Journ.* (1934).

Green, Dr. H. H.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

Kidd, Dr. F.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

Lovern, Dr. J. A.—In summary in *Nature*, **134**, 3395, p. 799, Nov. 24 (1934).

Macleod, Prof. J. J. R.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

MacWilliam, Prof. J. A.—Expected to appear in extended form in *Quart. Journ. Exp. Physiol.*, and *Brit. Med. Journ.*; cf. *Quart. Journ. Exp. Physiol.*, **23**, p. 1 (1933).

Mellanby, Dr. May.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934); cf. *No.* 191, *Special Report Series* (Medical Research Council, London, 1934).

Millikan, Dr. G. A.—*Nature*, **134**, 3392, p. 706, Nov. 3 (1934).

Moran, Dr. T.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

Orr, Dr. J. B.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

Poulton, Dr. E. P.—Expected to appear in *Guy's Hosp. Reports* and in book form; cf. *Journ. Physiol. Soc.*, **77**; *Journ. Roy. Soc. Med.*, **25**, Jan. (1932); *ibid.*, **26**, Oct. (1933).

Reay, Dr. G. A.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

Robertson, Dr. D.—*Nature*, **134**, 3389, p. 557, Oct. 13 (1934).

Roughton, Dr. F. J. W.—*Nature*, **134**, 3392, p. 705, Nov. 3 (1934).

Smith, Dr. E. C.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

West, Dr. C.—In summary in *Nature*, **134**, 3395, p. 798, Nov. 24 (1934).

Section J.

Binns, H.—Cf. *Journ. Text. Inst.*, **25**, no. 21 (1934); *Proc. VIIth Internat. Cong. Psych.*, Oxford (1923); *Pract. Educ. & School Crafts*, **21**, 233, 234, 235 (1924); *Wool Record & Textile World*, July 30 (1925); *Brit. Journ. Psych.*, **16**, pt. 3 (1926); *Journ. Text. Inst.*, **23**, no. 28 (1932); *ibid.*, **25**, no. 5 (1934); *ibid.*, **25**, no. 11 (1934).

Dodds, Miss G. B.—Cf. ' Leçons Vivantes ' (Dodds), Gregg Publ. Co.

Katz, Prof. D.—*Acta Psychologica*, **1** (Martinus Nijhoff, Holland, 1934); in summary in *Nature*, **134**, 3393, p. 744, Nov. 10 (1934).

Katz, Dr. Rosa.—Cf. *Zeitschr. für Kinderforschung*, **42** (1933) ; ' Gespräche mit Kindern ' (Katz, Berlin, 1928).

King, Rev. Dr. J. Leycester.—In extended form in *Archiv für gesamte Psych.* (Leipzig), **92**, p. 423 (1934).

Oakley, C. A.—Expected to appear in *Human Factor.*

Oeser, Dr. O.—Expected to appear in *Brit. Journ. Educ. Psych.*

Penrose, Dr. L. S.—Expected to appear in *General Report Res. Dept. Roy. East. Counties' Inst.* (1935) ; cf. *Special Schools Journ.* (1933) ; *Brit. Med. Journ.*, Jan. 6 (1934) ; *Eugenics Rev.*, July (1934) ; *Brit. Journ. Psych.*, **24**, July (1933) ; ' Mental Defect ' (Penrose), Sidgwick & Jackson (1933) ; ' Influence of Heredity on Disease ' (Penrose), H. K. Lewis (1934).

Pickford, Dr. R. W.—To be embodied in book yet to be published.

Vernon, Dr. P. E.—Cf. ' Yearbook of Education for 1935,' Evans Bros. (1935).

Wales, Miss J. A.—To appear in *Human Factor.*

Wiesner, Dr. B. P.—In summary in *Nature*, **134**, 3393, p. 745, Nov. 10 (1934).

Section K.

Benson, Dr. Margaret.—Cf. *Proc. Linnean Soc. Lond.*, **146**, pt. 1, p. 38 (1933–34) ; *Ann. Bot.*, July (1934) ; *ibid.*, Jan. (1935) ; *New Phytologist*, **1** (1935).

Blackburn, Dr. Kathleen.—Cf *Forestry*, **8**, no. 1 (1934).

Bond, Dr. G.—To appear in *Trans. Roy. Soc. Edin.*

Bryan, J.—*Timber Trades Journ.*, **130**, 3028, p. 680, Sept. 8 (1934).

Caldwell, Dr. J.—To appear in *Proc. Roy. Soc.*, B.

Dickinson, Dr. Olive D.—In extended form as ' Communication 31, Station Internat. Geobot. Medit. et Alpine, Montpellier ' (1934).

Doyle, Prof. J.—Expected to appear in *Proc. Roy. Dublin Soc.*

Graham, Prof. R. J. D.—*Trans. & Proc. Bot. Soc. Edin.*, **31**, pt. 3, p. 450.

Gregor, Dr. Mary J. F.—May appear in extended form in *Phytopathologische Zeitschr.* ; cf. *Ann. Mycologici*, **30**, p. 463 (1932).

Oxley, T. A.—Expected to appear in extended form in *Ann. Bot.*, April (1935).

Priestley, Prof. J. H.—Expected to appear in *Proc. Leeds Phil. & Lit. Soc., Sci. Section.*

Seifriz, Prof. W.—Cf. *American Naturalist*, **63**, p. 410 (1929) ; *Protoplasma*, **21**, p. 129 (1934) ; further matter to appear in *Journ. Rheology* (1935).

Smith, Dr. Edith P.—In extended form in *Scottish Naturalist*, Nov.-Dec. (1934).

Wilkinson, J.—Cf. *Forestry*, **8**, no. 1 (1934).

Department K*.

Dallimore, W.—*Gardener's Chronicle*, Nov. 10 (1934) and subsequently ; to appear in *Quart. Journ. Forestry* ; expected to appear in *Scot. For. Journ.* ; in summary in *Lecture Recorder*, **4**, 5, Dec. (1934).

Gorrie, Dr. R. McL.—*Timber Trades Journ.*, p. 753, Sept. 15 (1934).

Hutchinson, H. P.—To appear in *Roy. Scot. Forestry Journ.*; cf. *Annual Report, Long Ashton Res. Station* (1922, 1923, 1924, 1926, 1927, 1928, 1929, 1930, 1931, 1932, 1933); *Journ. Ministry Agric.*, July (1929); *Quart. Journ. Forestry*, April (1933); *Journ. Nat. Fedn. Women's Insts.*; *Nature*, Feb. 8 (1930); 'Economic survey of Somerset Willow Growing Industry' (Hutchinson), Univ. Bristol.

Stirling-Maxwell, Sir John.—To appear in *Trans. Roy. Scot. Forestry Soc.*; in summary in *Lecture Recorder*, **4**, 5, Dec. (1934).

Section L.

Development of post-primary education, discussion.—*Journ. Educ.*, **66**, 783, p. 649, Oct. (1934); *Times Educ. Suppt.*, Sept. 15 (1934).

Technical education and industrial recruitment, discussion.—*Journ. Educ.*, **66**, 784, p. 688, Nov. 1 (1934); *Nature*, **134**, 3395, p. 819, Nov. 24 (1934).

Bispham, J. W.—*Journ. Educ.*, **66**, 784, p. 688, Nov. 1 (1934); *Nature*, **134**, 3395, p. 819, Nov. 24 (1934).

Bond, Col. C. J.—Printed privately.

Duckworth, F. R. G.—*Education*, Sept. 21 (1934); summary in *Journ. Educ.*, **66**, 783, p. 649, Oct. (1934).

Fleming, A. P. M.—*Industry Illustrated*, Oct. (1934); summary in *Journ. Educ.*, **66**, 784, p. 688, Nov. 1 (1934); *Nature*, **134**, 3395, p. 819, Nov. 24 (1934).

McKechnie, W. W.—*Journ. Educ.*, **66**, 783, p. 651, Oct. (1934).

MacTaggart, Dr. Mary M.—To appear in *Teachers of the Blind* (Coll. of Teachers for Blind).

Norwood, Dr. C.—*Education*, p. 228, Sept. 14 (1934); *South Eastern Gazette*, Sept. 25 *seqq.* (1934); summaries in *Journ. Educ.*, **66**, 783, p. 650, Oct. (1934); *Times Educ. Suppt.*, Sept. 15 (1934); *Lecture Recorder*, **4**, 5, Dec. (1934).

Rintoul, W.—*Chemistry & Industry*, p. 868, Oct. 9 (1934); *Oil & Colour Trades Journ.*, p. 719, Sept. 14 (1934); summaries in *Industrial Chemist*, p. 369, Oct. (1934); *Journ. Educ.*, **66**, 784, p. 688, Nov. 1 (1934); *Nature*, **134**, 3395, p. 819, Nov. 24 (1934).

Stamp, Sir J. C.—*Journ. Educ.*, **66**, 783, p. 649, Oct. (1934); *Times Educ. Suppt.*, Sept. 15 (1934).

Thomson, G. W.—*Journ. Educ.*, **66**, 784, p. 688, Nov. 1 (1934); *Nature*, **134**, 3395, p. 819, Nov. 24 (1934).

Walker, Dr. N. T.—In summary in *Lecture Recorder*, **4**, 5, Dec. (1934).

Section M.

Cattle rearing and feeding, discussion.—*Aberdeen Press & Journ.*, p. 7, Sept. 7 (1934).

Archibald, Dr. E. S.—*Aberdeen Press & Journ.*, p. 7, Sept. 7 (1934).

Fenton, E. W.—Cf. *Agric. Progress*, **4** (1927); *Trans. & Proc. Torquay Nat. Hist. Soc.* (1925–6); *ibid.* (1931–2); *Journ. Ecol.*, **19** (1931); *Scot. Geog. Mag.*, **49** (1933); *Journ. Ecol.*, **22** (1934).

Grant, J. S.—*Aberdeen Press & Journ.*, p. 7, Sept. 7 (1934).

Hall, Sir A. D.—*Nineteenth Century and After*, p. 426, Oct. (1934); in summary in *Lecture Recorder*, **4**, 5, Dec. (1934).

McCallum, A.—*Scot. Journ. Agric.*, Oct. (1934).

Mackie, M.—*Aberdeen Press & Journ.*, p. 7, Sept. 7 (1934).

Muir, Dr. A.—Cf. *Forestry*, **8**, p. 25 (1934).

Page, H. J.—*Aberdeen Press & Journ.*, Sept. 7 (1934); cf. *Journ. Roy. Agric. Soc. England*, **95** (1934).

Rae, Prof. R.—*Journ. Ministry Agric., N. Ireland*, **4**, 1933; summary in *Aberdeen Press & Journ.*, p. 7, Sept. 7 (1934).

Watson, Dr. S. J.—*Aberdeen Press & Journ.*, Sept. 7 (1934); cf. *Journ. Roy. Agric. Soc. England*, **95** (1934).

APPENDIX

A

SCIENTIFIC SURVEY

OF

ABERDEEN

AND DISTRICT

PREPARED FOR
THE ABERDEEN MEETING
1934

BY VARIOUS AUTHORS

CONTENTS.

A SCIENTIFIC SURVEY OF ABERDEEN AND DISTRICT

I.

ABERDEEN IN ITS REGIONAL SETTING

BY

HENRY ALEXANDER, M.A.,

LORD PROVOST OF ABERDEEN.

THE North-east of Scotland, projecting, as it does, into the North Sea, and cut off from the south by the Grampian range of mountains, possesses a definite regional character which is reflected in the history and development of the district and in the attributes and interests of its people. The City of Aberdeen, with a population of 167,258 (census of 1931), is the largest centre of population in the region, the next largest town being Peterhead (population 12,545). As a manufacturing town, as a seaport with shipping connections and extensive fisheries, as a business centre for the agricultural and stock-feeding industries of the region, and not least as the seat of a university and other educational institutions, Aberdeen has varied and notable activities, while its isolation from all the other large cities of Scotland has contributed to its importance and emphasised its distinctiveness.

The three counties which are generally regarded as forming the North-east—Aberdeen (population, excluding City of Aberdeen, 133,178), Banff (population 54,907) and Kincardine (population 39,865)—are similar in character, with this qualification : that the southern portion of Kincardine tends to incline physically and economically to Angus and the northern midlands of Scotland. This distinction also accords with the dialectal boundary, marked out by Dr. William Grant in *The Scottish National Dictionary*, between South-Northern Scots and Mid-Northern Scots.

While the region of which Aberdeen is the chief town is primarily defined in this Survey as the North-east of Scotland, it is only right to say that the city is closely associated educationally and commercially with

the whole of the North of Scotland, including the Hebrides and the Orkney and Shetland Islands. The University of Aberdeen has always drawn a considerable proportion of its students from Inverness-shire and Ross-shire, and this connection is further exemplified in the Aberdeen and North of Scotland College of Agriculture and in the Aberdeen Provincial Committee for the Training of Teachers, both of which institutions, located in Aberdeen, have the North of Scotland, from Kincardine to Shetland, as their field. The shipping association between Aberdeen and Shetland is very close and the commercial links are further emphasised by the fact that the great herring fleets of the Aberdeenshire and Banffshire ports, such as Peterhead, Fraserburgh, Macduff and Buckie, proceed to the Shetland fishing in the early summer before undertaking the July and August fishing at their home ports.

The barrier of the Grampians, which begins on the sea coast immediately south of Aberdeen in a low range and which rises through various intervening heights to mountains as high as Lochnagar (3,786 ft.), has been an important factor in contributing to the distinctiveness of the North-east. It was known as *The Month*, from the Gaelic *monadh*, a heath—a term which still remains in certain place-names—and, though the effect of this barrier is now diminished under modern means of communication, it is still strong enough to influence the economic and cultural life of the region.

On its western border the region shades imperceptibly into Moray and Nairn and the Highlands, while it has also to be remembered that the higher uplands of Aberdeenshire and Banffshire, where the Gaelic speech still lingers, fall within what is known as the Highland Line and partake in their physical structure of the Highlands rather than the Lowlands. It is impossible to enter here into the details of racial origins—a fuller discussion of which, as of other points, will be found in subsequent pages—but it is reasonably correct to say that, while ethnically there is a large Celtic element in the population of the North-east, the region belongs culturally to the Anglo-Saxon Lowlands with a Norse or Danish strain along the coast.

The trading community at the mouth of the river Dee, which formed in time the town of Aberdeen, seems to have been, from the earliest historical days, English-speaking. What became known as Old Aberdeen was the burgh which grew up round the cathedral founded on the banks of the Don on the site of the missionary church traditionally ascribed to St. Machar, a disciple of Columba. The establishment of a university by Bishop Elphinstone in 1494 increased the academic as well as the ecclesiastical importance of Old Aberdeen, and the burgh, though now merged municipally in Aberdeen, still retains in its buildings and environs a distinct old-world aspect. While Old Aberdeen had its University and King's College, Aberdeen had its University and Marischal College, founded in 1593, and it was not until 1860 that the two universities were fused in one. The existence side by side for two and a half centuries of two separate and rival universities, while not without its absurd features, reflected in a sense the consuming passion for education which marks out the people of the North-east even in Scotland, and the influence of which is to be seen in so many directions in their aims and outlook.

The conditions of life have never been easy in the North-east. By the labour of successive generations and with infinite toil the farm lands have been won from the moorland and waste ; to-day in the higher lying parts of the region, as in other parts of Scotland, fields which had fifty or a hundred years ago been brought under the plough, are now, owing to changed economic conditions, reverting to moorland. The climate is dry, the average rainfall being about 30 in. per annum, but it cannot be described as genial. Rather is it rigorous and bracing, and this and the absence of great natural wealth in the district have produced a strong, hardy race of people, enured to toil and accustomed to self-denial, but full of resource and resolute for progress. The qualities supposed to be typical of Scotsmen are to be found raised to the *n*th degree in the people of the North-east. They are a folk reserved and shy and lacking perhaps in the outward graces of life, but it would be a complete mistake to think that they are wanting in imagination or in artistic appreciation, for in the past the countryside was rich in ballad lore, and to-day, in the movement for community drama and acting which is such a happy feature of rural life, the North-east sends forward a larger number of competing teams in proportion to its population than any other part of Scotland.

While the North-east cannot boast any writer of the class of Burns, Scott, or Carlyle, it can claim an exceptionally large roll of men of high competence and ability, particularly in the field of science and medicine. Prof. James Ritchie, in a paper on ‘ The Genius of the Aberdonian ’ (*Aberdeen University Review*, vol. xv, pp. 193–205), describes the mentality of the Aberdonian as ‘ a bent for minute, detailed work ; for accuracy in the small things.’ This has found expression in scientific work, and especially in the practical application of scientific knowledge, and in a subsequent article an account is given of leading names in this field. At the same time it is only right to say that in other walks of life—in classical study, in letters and in art—names not a few might be cited which evidence the all-round capacity of the people.

II.

GEOGRAPHY OF THE NORTH-EAST

BY

JOHN McFARLANE, M.A., M.Com.

A VISITOR to Aberdeen, taken to Rubislaw Quarry on the western margin of the city and shown the surrounding country from the height of a small eminence there, might at first be surprised to learn that, if he were to proceed due west from where he stood, it would be necessary for him

to cross North America, Asia, and part of Europe before he came to, or passed to the south of, a town as large as that which lay at his feet. Only when he reached the shores of the Baltic would he find Leningrad, Stockholm, and a few other towns lying in or beyond the latitude of Aberdeen, and equalling or surpassing it in importance.

This almost unique position attained by Aberdeen naturally directs attention to the region in which it lies. If our visitor turned to the south he would, on looking across the valley of the Dee, see in the near distance the last spurs of the Grampians, the southern limits of the region of which Aberdeen is, if not the centre, at least the capital. The attractive force of the city rapidly decreases to the south of that gap which lies between the hills and the sea, and by which road and railway alike leave for the south. It is to the north and west that the true hinterland of Aberdeen is to be found, and the city, lying just to the north of what may be termed the Stonehaven Gap, is by good fortune situated where it can best serve the varied interests of that hinterland. Nevertheless an explanation of Aberdeen in terms of its environment is by no means as simple as might at first sight appear.

Within the area under consideration several well-marked physical regions may be recognised. The high massifs of Lochnagar and the Cairngorms in the south-west are replaced farther east by the lower valleys of the Dee and the Don, while to the north of the Don lies the well-worn peneplain which includes Buchan and some of the lands adjacent to it. In the north, that part of the Highlands which lies beyond the Cairngorms and is drained by the Deveron and the Spey falls away to the lowlands bordering the Moray Firth. But on the whole these regions possess few geographical advantages. It was only with difficulty that even the most suitable areas could be made fit for cultivation. The glaciated lands had first of all to be cleared of their boulders, the ground drained, and the peat-mosses reduced in size. Moreover, the soils which are the product of the glacial period have not yet undergone complete chemical weathering, and, though not infertile, are seldom rich ; the climate, as will be seen later, is somewhat harsh, and the mineral wealth, apart from granite, is inconsiderable. The economic activities of the people are mainly concerned with agriculture, except along the coasts, where various towns and villages have become the local centres of one of the chief fishing areas in the country.

Deeside.—The Dee for a great part of its course flows between the great granitic massifs of Lochnagar and Mount Battock in the south and the Cairngorms with their eastern extensions in the north. Its valley which runs from west to east is in that respect anomalous, as most Highland valleys run either from north-west to south-east or from north-east to south-west, and may be a tectonic hollow produced by the upwelling of the granitic masses to the north and south. From its source high on the slopes of Braeriach, the Dee falls nearly 2,000 ft. to reach the Linn of Dee. During this part of its course it flows through wild and uninhabited highland country, but below the Linn it enters an alluvial flat, the fertility of which may have contributed to the growth of Braemar, though the precise position of that village was fixed at the meeting place of two

routes across the Mounth. To-day it owes its prosperity to its nearness to the Cairngorm country, Braeriach, Cairn Toul, and Ben Muichdhui—all over 4,000 ft.—being easily accessible from it.

Below Braemar the valley of the Dee again becomes contracted and remains so until below Balmoral. It then gradually opens out to the alluvial plain on the edge of which Ballater stands. This plain was once occupied by the ice-sheet, and the Pass of Ballater, through which the old Deeside road formerly went, is mainly due to glacial erosion. Ballater itself is the terminus of the Deeside railway and is a typical Highland summer resort.

After Ballater the valley of the Dee opens out as the hills recede. Some of the more interesting features of its basin as far as Banchory may be noted. Loch Kinord, the site of old lake dwellings, lies to the north of the river and is believed to owe its origin to a mass of ice left stranded during the retreat of the valley glacier. The Muir of Dinnet, which was built up by outwash gravels from the glacier, is, when the heather is in bloom, one of the most beautiful spots on Deeside. The old lake basin of Tarland has been drained and converted into good agricultural land, but the similar basin of Auchlossan, farther to the east, is again under water. The erosion basin of the lower Feugh (which rises in the Mount Battock massif and joins the Dee at Banchory) shows abundant evidence of glaciation—severed spurs at Castle Hill, the esker at the Feughside Inn, kettle holes at Bogarn, and moraines in various places.

Banchory, on a southward facing slope protected from cold northerly winds by the Hill of Fare, and at the junction of various hill routes with the main Deeside road, grew up as a market town, but has developed into a residential and health resort. Lower down, the basin of the Dee contracts as it becomes wedged in between the last outliers of the Grampians and the Dee-Don watershed. The river terraces which lie along the north side of the Dee for the last few miles of its course provide admirable sites for a long line of suburban residences.

The economic resources of the whole region just described are limited. Agriculture is the chief pursuit of the inhabitants. To the west of Ballater sheep-rearing comes first in importance; to the east, arable farming becomes more general, oats and turnips are the principal crops, and cattle to some extent replace sheep. Below Banchory barley is a not unimportant crop. There is little industrial life. Saw-milling at various places, paper-making at Culter and quarrying at Rubislaw about exhaust the list. Summer holiday traffic is an important source of income to the whole valley.

Donside.—The basin of the Don falls into several well-marked divisions. In the north there is a highland region divided into two parts—an eastern and a western—by the Kildrummy basin. The western consists of the Cabrach massif and the eastern of the Correen-Bennachie range. To the south of the Don another belt of upland country which forms the watershed between the Dee and the Don is more complicated; in the west it contains the great conical mass of Morven, and in the east the long drawn-out Hill of Fare. The valley of the Don which lies between differs in various respects from that of the Dee. One of its most

characteristic features is the alternation of close gorge and open reach which becomes well marked near Towie, and exercises a considerable influence upon the distribution of population. The Towie and Kildrummy basins, which have been excavated out of the Old Red Sandstone, form the first regions suitable for settlement as we come downstream apart from the alluvial strips along the river and its tributaries. The Kildrummy basin is of special interest as it provided a lowland through which passed the road from the western passes of the Mounth to the north by way of Huntly. On this important strategic route, and in a relatively fertile district, rose Kildrummy Castle, the largest castle in the north of Scotland. The Alford basin is more extensive and even more distinctive. The river enters and leaves it by water gaps over 1,000 ft. deep, and only at one other point are the surrounding uplands much below 1,000 ft. The basin, in the formation of which glacial erosion has played a large part, contains a considerable amount of good agricultural land. Lower down, the Don passes through the Kemnay and Kintore basins, which are, however, less decided in character than those already mentioned.

An important point of difference between the Dee and the Don is that while the Dee is well graded the Don has been rejuvenated, not by uplift but as a result of glacial action. The ice streaming across its valley filled it with gravels and boulder clay, and when the river returned it found itself forced in places on to harder rock, with the result that its gradient was changed. Hence water power is more abundant in the valley of the Don than in that of the Dee. On the whole, too, the valley of the Don is the more fertile. The fluvio-glacial soils which occupy considerable areas in the valley of the Dee absorb water easily and the region often suffers from drought. For this reason it has been said that one day's rain will do for the Don what it takes two days' rain to do for the Dee. That the agricultural importance of the lower Don was considerable even in prehistoric times is indicated by the stone circles, which are more numerous, especially near Inverurie, than in other parts of the county ; the numerous castles of medieval times bear witness to the same fact.

Among the more important settlements in the basin of the Don the following may be noted. Alford is situated in the fertile Howe of Alford, nearby the ford which crosses the Don, and in the central part of the basin ; it is only a small village, but it forms an admirable market place for the surrounding district, and gains by the fact that it is the terminus of the Donside railway. Kemnay was merely a hamlet until the opening of the granite quarries in the neighbourhood. Kintore is situated just above the remains of a great fluvio-glacial fan which must have stretched far across the Don valley, and just below the low ground near the river ; it has been a Royal burgh since the days of William the Lion. Inverurie is situated at the confluence of the Don and the Urie at a point where routes to the north must cross the Don. The town is built partly on the lowest slopes of another great fluvio-glacial fan which must at one time have almost blocked the Don. The Bass of Inverurie, a severed spur of this fan, most of which has been destroyed, may have given the town some importance in early times ; in medieval days it was the site of a feudal castle. The modern importance of Inverurie dates from the

beginning of the nineteenth century, when a canal, now disused, enabled it to become the centre of an agricultural area.

Although agriculture is even more important than in the preceding region it does not predominate over all other industries to the same extent. Granite is worked on an extensive scale, the largest quarry being at Kemnay just above Kintore. There are a number of others in this region (some of which are no longer worked), but it may be noted that nearly all of importance are to be found near the edges of the granitic mass.

The Don, as already indicated, is an important source of water power. During the last seven miles of its course it falls 100 ft.—at one place the rate of fall is 27 ft. per mile—and it is to the power thus provided that the original establishment of mills and factories in the Don valley is due. In this part of its course also, the river fortunately does not flow in a continuous narrow gorge; in the process of cutting down its bed, it has cut on alternate sides flat haughs which provide excellent sites for the erection of factories. Even to-day when steam-driven engines provide most of the power required, the river is utilised for the generation of hydro-electric power; in addition water from the river is used in various manufacturing processes. Among other industries which started here in the eighteenth century that of cotton was at first one of the most promising; it was unable, however, to contend against the economic organisation of the Lancashire industry and the attempt had to be abandoned. At the present time the manufactures of paper and woollen goods are by far the most important.

Buchan.—Buchan, which is generally regarded as being bounded on the west by the Deveron and on the south by the Ythan, has a well-marked individuality. It may be described as a low-lying peneplain of ancient rock, and except in a few places it does not exceed 500 ft. above sea-level, while a large area in the north-east and east is below 250 ft. In the south the most important heights are those which separate the basins of the Ugie and the Ythan; in the north the Windyhead and Braclemore Hills rise to over 700 ft. The granites and schists along the coast have weathered into many picturesque formations.

The soil varies in character and fertility, but for the most part consists of boulder clay. Partly because of the absence of trees over considerable areas, the country presents a somewhat bleak appearance, and indeed it was not till the eighteenth century that a real attempt was made to clear from its surface the glacial boulders with which it was strewn, and to drain the bogs which were relics of the Ice Age.

Cattle raising is an important pursuit and the whole agricultural economy of the region is based upon it. Over four-fifths of the land is either cultivated or under grass, oats, turnips and swedes, and rotation grasses being the principal crops. The uniformity of practice throughout the whole area is well illustrated by some recent figures: 'of the nineteen parishes in the area under consideration all but two devote from 11 to 13 per cent. of the farmed area to turnips and swedes, all but two have between one-third and one-fourth of the same area under oats, and in all but one the percentage of rotation grass varies from 40 to 50 per cent., in most cases lying between 43 and 47.' For this type of farming the

country is well suited, as climatic conditions are particularly favourable to the cultivation of turnips, and only to a slightly less extent so for the cultivation of oats.

As a result of these agricultural conditions the distribution of population throughout Buchan is on the whole remarkably uniform away from the coast. The hilly districts naturally have fewer inhabitants; on the other hand, there are no large towns, only villages, such as Strichen, Maud, New Pitsligo and Old Deer, which serve as agricultural centres. On the coast there are many smaller villages which engage in line fishing, now decreasing in importance, but the two towns of importance are Peterhead and Fraserburgh. The former was in the earlier part of the nineteenth century the chief whaling port in the north of Scotland, but like Fraserburgh its main interests are now in the herring fisheries. Fraserburgh formerly provided an interesting case of *transhumance*. At the beginning of the season, which lasted for about three months, fishermen collected from all quarters, bringing with them not only their boats and tackle, but their wives, children, and even some of their domestic furniture. This practice, however, appears almost to have passed away as a result of the introduction of steam drifters and motor boats.

Deveron to Spey.—To the west of the Deveron and upper Ythan the land lying north of the hills which border Strathbogie is merely a continuation of the Buchan peneplain, and, though somewhat higher, seldom much exceeds 700 ft. Farther to the west the lowland becomes more contracted as the Highland hills advance to the north. The Deveron itself rises in the wild recesses of the Cabrach and flows through the region in a series of west to east and south to north stretches, the result of various captures which have taken place in the past. The greater part of the surface is covered with boulder clay, the character of which varies with the underlying rocks.

In the eastern part of the region economic conditions are not very dissimilar from those of the Buchan peneplain ; nevertheless the warmer climate of the coast of the Moray Firth is beginning to make its influence felt, and barley and sugar beet are among the crops grown. Farther west, in the region which contains much of the hill country of Banffshire, the cultivated land occupies less than one-half of the total area, and of it a larger proportion than usual is under grass. The upper part of the Deveron basin is one of the most isolated areas in the whole of the North-east, partly due to the trend of its river valleys preventing easy communication with Aberdeen which would otherwise have proved its most profitable market. Along the coast there are a number of fishing towns the exact position of some of which have been described in *Memoir* 86 of the Geological Survey: ‘ The harbours of Findochty and Portnockie are constructed in breached anticlines, Cullen harbour lies in the shelter of Cullen Bay and Sandend in Sandend Bay ; Portsoy uses a cleft in the igneous rocks ; Whitehills is protected from the east by the promontory of Knock Head ; Banff and Macduff lie on opposite sides of Banff Bay at the mouth of the River Deveron.’ Another point of interest with regard to the larger of the coastal towns, not only in the district immediately under consideration but from Stonehaven northwards, is that the section

of the town actually engaged in fishing is always built on a lower level—often a low raised beach—than the remainder. This of course was necessitated by the need of easy access to the sea, but it led to a segregation by the fishing folk which has had important social results.

The chief inland towns of the region are Turriff, Huntly and Keith. All are route centres and because of this have become agricultural market towns.

Aberdeen.—Having surveyed the region of which Aberdeen is the capital, we now turn to that capital itself. To its growth land and sea have alike contributed. Placed just north of the most easterly of all the passes across the Mounth, and between the mouths of the Dee and the Don, it also lies at the apex of the Buchan plain which constitutes the most fertile part of its hinterland. The original settlement may have been at the mouth of the Don (whence the name Aberdon which in the local dialect became Aberdeen), but the mouth of the Dee offered a useful harbour while that of the Don did not. The town at the mouth of the Dee may or may not have originated as a Teutonic settlement ; at any rate about 1180, when it received a charter, it was a trading centre and port, while the Church of St. Nicholas, the patron saint of traders, is of even earlier date. For centuries Aberdeen was mainly dependent upon its hinterland, the products of which—wool, hides, furs and salmon—were exported to the Continent. Later on Flemish weavers introduced the woollen industry, and in the seventeenth century town and country were alike engaged in the manufacture of cloth, just as in the eighteenth century they were in that of hosiery. With the Industrial Revolution domestic industries became of less importance, and Aberdeen, far from coal, was at a disadvantage, though some compensation was found in the water power of the lower Don, and the paper-making and woollen industries established there have persisted. For a short period in the middle of the nineteenth century Aberdeen became noted for the building of wooden ships, such as some of the China clippers, but the most important feature of modern times has been the development of the fishing industry with all the subsidiary industries connected therewith—fish-curing, marine engineering and shipbuilding. Aberdeen now takes third place among the fishing ports of Great Britain.

The growth of Aberdeen during the nineteenth century is indicated by the fact that the population increased from 27,000 at the beginning of the century to 153,000 at the close, and is now over 167,000.

III.

GEOLOGY

Geological boundaries ignore the limits of counties and parishes; but for present purposes it will be convenient to treat the Aberdeen area as comprising, mainly, the counties of Elgin, Banff, Aberdeen and Kincardine. The bed-rock within this area, while adequately exposed, is widely blanketed by sheets of glacial drift and incoherent deposits of recent date. The geology, therefore, falls naturally into two divisions:

I. The foundation rocks, or Solid Geology;

II. The overlying loose deposits, or Surface Geology.

With the latter may be included a consideration of the agencies that have moulded relief and influenced scenery.

I. SOLID GEOLOGY.

BY

Prof. A. W. GIBB, M.A., D.Sc., F.R.S.E.

The most notable structural feature is the line of fracture known as the *Highland Fault*, which, cutting across Scotland from west to east, strikes the coast-line near Stonehaven and divides the district under consideration into two sharply contrasted geological areas. South of the fault lie normal sediments of Old Red Sandstone and younger age; north of it, and sweeping westwards towards the Spey valley, lie masses of more ancient crystalline rocks. These older rocks are in places overlain by undenuded fragments of younger systems. The several formations may be briefly considered in order of age.

A. Pre-Cambrian.—The oldest rocks and the most widespread are metamorphic rocks. Of the three groups of rocks, of indefinite age, that occupy the greater part of Scotland between the Caledonian Canal and the Highland Fault—the Moines, the Dalradians and the small group sometimes called Lennoxians—those of the North-east are usually regarded as *Dalradians*. That is to say, they are the same rocks as those of the Central Highlands of Scotland. They have the same N.E.–S.W. trend and, lithologically, they have a general resemblance to the typical groups of Perthshire. They are now gneisses, mica-schists, quartzites, slates, etc., but they were once normal sediments, sandstones, clays, limestones; they contain also abundant igneous intrusions. Even in their metamorphosed condition they frequently retain their old bedding planes and other features characteristic of sediments. One significant feature they lack: they have been searched

in vain for fossils—searched so diligently, that probably now those who know them best would be most surprised to find recognisable organisms in them. Yet many of them seem less altered than rocks that in other formations are very fossiliferous. There is no reasonable doubt that they are older than the earliest fossil-bearing groups—that is, they are pre-Palæozoic in age.

They have a wide distribution in the North-east. Inland exposures are often obscured by surface drifts, but along the coast. from Cullen in the north to Stonehaven in the south, they are exposed in a section over seventy miles long. On the shore of the Moray Firth, from west of Cullen to Gamrie Bay, the rocks are laid bare, with few gaps, for some twenty-five miles. This section has been frequently described, the most detailed account being that of Prof. H. H. Read, who re-surveyed the ground recently for the Geological Survey. One of the interesting facts that emerge is that the Moray Firth group falls into two series, the western (known as the *Keith Division*) showing a higher grade of metamorphism than the eastern (the *Banff Division*). The two are separated from one another east of Portsoy by a definite structural break, known as the 'Boyne line.' While the Keith division is generally accepted as a northerly extension of the Perthshire series, the Banff division appears to be unrepresented in Perthshire, perhaps even anywhere in Scotland, unless it may correspond in a measure to the Loch Awe group (S.W. Highlands).

The metamorphic series is continued eastwards along the coast through Fraserburgh to Peterhead and thence southwards to Aberdeen, but the continuity is interrupted by blown sand-drifts and igneous intrusions. South of Aberdeen, these rocks build a continuous coast-line for fifteen miles—a fine section, though frequently inaccessible from land owing to the precipitous character of the cliffs. It consists of coarse gneisses, mica-schists, hornblende-schists, quartzose chlorite-schists and other types, interleaved with granite injections, penetrated by pegmatite dykes and felsite sills, by dolerite dykes and some amygdaloidal rocks, and carrying, in some belts, minerals of high-grade metamorphism like Sillimanite and Staurolite. The metamorphics terminate abruptly against the Highland Fault just north of Stonehaven.

The rocks of the coast sections can be followed inland, still maintaining the same general strike as the coast series, and with the same trend as their supposed equivalents in Forfarshire and Perthshire—from which, however, they are almost severed by the intrusive masses of the Grampian Granites.

The Dalradian age of these rocks is not admitted by all : the more westerly members of the Keith group have been sometimes regarded as belonging to the Moines ; certain members of the Banff group have been correlated with the Lennoxians ; and by some, the whole sequence from Peterhead to Muchalls (Stonehaven) has, again, been referred to the group of the Moines.

The age, the metamorphism, the structural relations, the stratigraphical sequence of these rocks are all still very obscure : their full elucidation promises to be another battle-ground of Scottish geology.

The metamorphics have been broken into time and again by igneous rocks which occupy a very considerable extent of the exposed surface of the area. The later igneous intrusions are dominantly acid—granites and their allies ; but there are also basic types—picrites, gabbros, norites and other varieties. These latter are more restricted in distribution than the granites, occurring as isolated masses in upper Deeside, Donside, and especially in central and eastern Aberdeenshire (Belhelvie, Haddo, Maud, Insch, Huntly and elsewhere). The intrusions, acid and basic alike, are manifestly of different ages, and while much diversity of opinion exists as to the date of intrusion, and while no criterion is yet known by which the age in every particular case may be definitely established, the igneous rocks may be roughly grouped into an ' older ' and a ' younger ' series. The older are represented by an intrusion or series of successive intrusions antedating or accompanying the earth-movements that foliated the metamorphics ; the younger by an intrusion or a succession of separate intrusions later on the whole than the folding movements. The granites show a great variety of types, not fully explained, though the variation may be due, in part, to incorporation of the material into which they were intruded. Contamination of igneous masses by the assimilation of pre-existing rock is most clearly exemplified in the case of the basic intrusions. The phenomena have been worked out in detail about Huntly and eastern Aberdeenshire by Prof. Read, and the area has become the most instructive in Britain for the study of this aspect of igneous activity.

B. Palæozoic.—Of the ordinary fossiliferous systems that form the geological ground-work of most other parts of Britain, the North-east of Scotland shows scarcely a trace. Perhaps it is all the more remarkable, therefore, that actual traces of most of them do exist—Cambrian, Silurian (?), Old Red Sandstone, Permian, Trias, Jurassic, Cretaceous and even Tertiary deposits have all been recognised. Most of these are of small size, many of them are not even proved to be *in situ* ; but they are of considerable theoretical interest.

Slaty rocks of *Cambrian* (or *Ordovician*) age, scantily fossiliferous and associated with pillow-lavas and radiolarian cherts, are exposed on the coast a mile north of Stonehaven, where they are faulted against the metamorphics along the ' Highland Border.'

They are succeeded southwards by a thick series of *Downtonian* (*Upper Silurian* ?) sediments, also fossiliferous, which merge imperceptibly into the normal Old Red Sandstone just opposite the town of Stonehaven. This section has been described in detail by Dr. Campbell of Edinburgh and rivals in interest the section along the Moray Firth already mentioned. Southwards from Stonehaven, the *Lower Old Red Sandstone* forms many miles of the coast, where massive conglomerates and interbedded lavas are sculptured into rugged cliffs that make a beautiful coast-section, scenically as well as geologically. Inland they form an open fold, the ' Strathmore Syncline,' which expresses itself superficially as the ' Howe of the Mearns.'

But the Old Red Sandstone appears to have covered at one time the whole of the North-east of Scotland, for remnants of the formation are

abundantly found in the crystalline area north of the Highland Fault. It is quite frequently exposed in artificial openings within Aberdeen itself. In the Geological Museum of the University there is a core taken from a deep boring driven at Sandilands Chemical Works, in the centre of the town, which went 600 ft. through Old Red Sandstone conglomerate without reaching the underlying granite. Another familiar town section is the right bank of the river Don, between the old and new bridges, which is a high cliff of Old Red Sandstone. Outliers of a larger size occur between Turriff and Gamrie Bay, along Strathbogie (the Rhynie area), in the Elgin district, at Tomintoul and elsewhere. The Gamrie section is well known for its abundant fish fauna, proving its *Middle Old Red Sandstone* age. The Rhynie patch, now famous for its plant remains, is usually regarded, though less certainly, as of Middle Old Red age. Fossils, such as Eurypterids, are occasionally found in the sandstone quarry and may yet establish more definitely the horizon. The Old Red beds of Moray Firth localities have yielded many fossils, as, for example, the fish-bed of the Tynet Burn near Fochabers.

C. Mesozoic.—At Elgin the interest of the Old Red Sandstone has been overshadowed by *Permo-Triassic* (or ' New Red ') deposits, which have a total extent of some nine miles. Their reptilian remains were exhaustively described by Huxley and others about 1860. Many new forms have been found since that time.

Some fifty years ago a most unexpected mass of clay, crowded with *Jurassic* fossils (of Kimmeridge age), was exposed at Plaidy in central Aberdeenshire. The clay rests on boulder-clay and is no doubt ice-carried from the Moray Firth area. A similar Jurassic clay, full of Ammonites, is found on the coast at Blackpots, near Banff.

The remnants of the *Cretaceous* system are even more suggestive. Over a ridge of high ground in East Aberdeenshire, from near Ellon to Sterling Hill, south of Peterhead, great numbers of rolled flints can be picked up off the fields. They are full of Upper Chalk fossils. Collections of these are kept in Aberdeen University and the British Museum. In the same neighbourhood, at Moreseat in the parish of Cruden, there is known an extensive deposit of ' Greensand ' several hundred yards long and 30 ft. thick, crowded with fossil casts of Lower Cretaceous (and perhaps Upper Jurassic) age. Pebbles of White Chalk itself are not uncommon in Aberdeenshire clays, and though Chalk has nowhere been found *in situ* it has been dredged from the sea-floor off Fraserburgh, and trawlers frequently bring up large flints from the bed of the North Sea. And finally, a large collection of Cretaceous (Neocomian) fossils from gravel-pits near Fraserburgh was described last year in the *Geological Magazine* by Cumming and Bate, who regard the deposits as ice-carried from the Moray Firth district. The White Chalk pebbles found in Aberdeenshire, as pointed out some years ago by William Hill, are lithologically unlike other British and foreign chalks, and may represent higher zones of the Chalk, not known elsewhere, laid down on the extreme northerly shallow-water margin of the old Chalk Sea.

D. Tertiary.—Even of Tertiary times there are tattered fragments known. Some curious mounds called the Kippet Hills—near Collieston,

about twenty miles north of Aberdeen—have been found to contain ice-worn *Pliocene* shells ; and near Fyvie (at Windyhills) and Turriff (at Delgaty) in central Aberdeenshire, as also along the high ridge eastward from Ellon, there occur considerable spreads of post-Cretaceous gravels (with flints derived from the Chalk). They are not river-gravels, they cannot be shown to be glacial, and are referred (with some hesitation) to the Pliocene. Rocks of Pliocene age (*Coralline Crag*) are known, probably *in situ*, on the floor of the sea east of the Orkneys.

Fragmentary as these deposits are, they are yet eloquent of the changes that the North-east of Scotland has seen since Old Red Sandstone times.

The history of the North-east becomes more detailed and consecutive again as Tertiary time merges into the *Quaternary*, which is dealt with in the article that follows.

II. SURFACE GEOLOGY.

BY

ALEX. BREMNER, M.A., D.Sc., F.R.S.E.

A. Development of River System.—The theory of Mackinder, adopted for Scotland by Peach and Horne, that Scottish rivers originated on a peneplain, elevated in Early to Mid-Tertiary times and tilted towards the south-east, requires modification. North of the latitude of Inverness the original drainage lines did run north-west and south-east ; elsewhere in Scotland they followed west to east lines, e.g. the through-valleys west of the Great Glen, the Leven-Blackwater-Tummel, Earn, Forth (according to Cadell), Tweed, and the Solway-Tyne river. The peneplain, which included most of the British area, was warped during elevation (particularly along old lines of weakness) and its slope varied from one region to another ; at later dates, too, there occurred slight movements both of subsidence and elevation, e.g. the uplift that rejuvenated the lower Spey.

In the area under discussion the older rocks of the tilted peneplain must have been largely swathed in a mantle of Middle Old Red Sandstone, with probably younger rocks including some deposits of Cretaceous age : the widely distributed outliers of Old Red are very suggestive. The Tertiary drainage lines were therefore established on an east-sloping surface mainly of Old Red Sandstone.

Rivers in course of time cut through the weak, unmetamorphosed sedimentary cover and became superimposed on the more resistant, metamorphic Highland Schists which the valleys marking the older lines of drainage now cross regardless of structure.

Of older lines of drainage the most evident are (1) the well-marked, winding hollow, roughly parallel to the Moray Firth coast and extending from north of Binn of Cullen to Boyndie Bay ; (2) the transverse valley running from Mulben (Rosarie Burn) by Keith to Rothiemay (Isla) and Turriff (Deveron) and thence in a gentle S-bend by the Idoch Water and Ugie to near Peterhead ; (3) the hollow passing from Cabrach by

Rhynie and between the Correen-Bennachie and the Foudland ridges through the wind-gap at Oldmeldrum to the lower Ythan; (4) the valley of the Don; (5) the valley of the Dee.

In course of time the present drainage system has been evolved by (*a*) development of subsequents on the sedimentary fillings of pre-Old Red valleys in the schist floor; (*b*) adjustment of streams to the structure of the schists laid bare by removal of the sedimentary cover, e.g. capture of streams flowing at higher levels by tributaries working back from others that had cut their beds lower, these depredations usually being favoured by belts of weak rocks or weak rock-structures (shatter-belts along fault-lines, etc.).

Of such adjustments in times geologically recent but in all cases pre-glacial there are many instances. The annexation of the Tarf drainage area by the Tilt ought to be regarded as the classical example of river capture in the British Isles: it would indeed be difficult to find a clearer or more striking case anywhere. Map-study reveals self-evident cases of beheading at earlier dates of the primeval Tarf.

The capture of the upper Geldie by the Feshie has often been cited as an obvious case of river capture, which it is; but it is commonly stated to be of recent (i.e. post-glacial) date. That is not so. Capture was pre-glacial, and glacial erosion followed by glacial deposition has so altered the contours about the elbow of capture that absolutely none of the marks of recent capture are to be recognised.

In the complicated history of the Spey one point only can be noted. Above Grantown the gradient of the river is low; from Grantown to the sea there is an almost uniform fall of 16 ft. per mile. In this part of its course the river has been rejuvenated and here we find the characteristic mark of rejuvenation—an inner, narrow, young valley incised in the floor of an outer, wide, old valley. The inner valley is deepest in the vicinity of Knockando, and the axis of uplift must cross the river there, not at Grantown as usually stated.

B. Glaciation.—Within most of our area the distribution of erratics from the outcrops of all rocks yielding readily identifiable boulders shows that the direction of ice-movement varied widely at different periods of the Ice Age. For example, boulders from the Huntly basic rocks have been transported towards all points of the compass between N. 50° W. round by E. to S. 20° E. The diorite of Netherley (on Burn of Rothes) has been carried in similar but still more widely divergent directions.

From this wide dispersal one infers the action of more than one ice-sheet, an inference confirmed by study of striæ and boulder clays. At least three ice-sheets have successively traversed the area. Hence it is to be expected that the drift series will be complicated and difficult to interpret. Three characteristic drifts, however, can be identified with certainty, though between the Findhorn and the North Esk only four open sections show all three in direct superposition and only two show three superposed boulder clays.

(1) *First Ice-sheet.*—The transport of erratics, the direction of striæ, and the character and contents of the ground moraine clearly prove that the ice traversed our region roughly from N.W. to S.E. This was no

mere local movement, for striæ pointing between S. and S.E. are found from Elgin by Fraserburgh, Huntly and Fyvie to a point three and a half miles north of the Firth of Tay. Erratics from the N.W. are found as far south as Stonehaven and probably as far as Gourdon and Johnshaven: they include Cambrian 'pipe rock' and Torridonian sandstone, Elgin sandstone and Huntly rocks. Sutherlandshire granites (e.g. Rogart granite) have been transported to Elgin.

(2) *Second Ice-sheet.*—The coastal strip from Stonehaven to beyond Peterhead was traversed from S.S.W. by ice which brought with it a copious red bottom moraine, formed by the grinding up of the soft red shales of the Strathmore syncline, and erratics from the Old Red shales, sandstones, conglomerates and lavas.

Striæ, erratics and boulder clays prove that ice with which the 'Strathmore Ice' coalesced moved northward towards the whole south coast of the Moray Firth from Fraserburgh to Inverness.

The paths of both these ice-sheets were abnormal—not such as ice able to move out freely from the Scottish centres of accumulation would have chosen; and this holds true even if those centres were not the same for both, as was very probably the case. The Scottish ice was evidently compelled to turn south-east and south in the one case and north and finally north-west (across Caithness) in the other by the presence of Scandinavian ice in the bed of the North Sea. It is inconceivable that while Scandinavian ice continued to occupy the North Sea there could be in North-east Scotland a deviation from the earlier movement from the north-west to the later movement from the south without very extensive deglaciation. At two places peat and peaty material caught up in the red ground moraine of the Strathmore Ice give indication of an interglacial period of mild climate, and of the probably complete disappearance of the ice before the advent of the Second Ice-sheet. In the Burn of Benholm the red boulder clay enclosing peat rests on the dark shelly boulder clay discussed below.

Scandinavian Ice in Scotland (?).—In recent years quite a number of easily recognisable Scandinavian erratics (rhomb porphyries, laurvikites) have been found in North-east Scotland, particularly at Bay of Nigg (14 boulders): one was discovered nine miles inland.

A dark shelly boulder clay occurs at a number of localities in Aberdeen and Kincardine. No Scandinavian boulders have yet been found in it, but the fact that it contains numerous shells, most in fragments and many striated, shows that the ice of which it formed the ground moraine must have traversed the sea-floor. This shelly clay seems to be the lowest and oldest of all the glacial deposits in the districts where it is found. If the Scandinavian ice did not actually bring in the shelly clay, its pressure offshore forced in upon the land from the north-eastward part of the native ice that had previously passed over the bed of the North Sea. The aggregation of boulders at Bay of Nigg suggests that there the Scandinavian ice must have invaded or closely approached our shores.

(3) *Third Ice-sheet.*—Mers de glace from the Northern Highlands and from the region east and west of the Great Glen converged on the head of, and moved eastward along, the Moray Firth. From Elgin onward the

ice tended to shoulder in upon the land. This local movement from north-west and north is very well marked in the hollow connecting the Deveron and Ythan basins from Banff to Fyvie. The Banffshire Hills, the Cairngorms and the Central Highlands all contributed their quota to the Third Ice-sheet.

The position of the ice-front at the maximum of this glaciation has not yet been traced in every district. From near Fraserburgh to the Ythan the ice failed to reach the coast. From the Ythan to Aberdeen its front lay out to sea, but it struck the land again at Bay of Nigg. From that point to near Cortachy its position can be traced with some precision: it nowhere transgressed the Highland Boundary Fault except for short distances on the Bervie Water, North Esk and West Water. At Cortachy and beyond the ice seems to have spread across Strathmore and the southern Sidlaws.

C. Soils.—Only in disconnected and very restricted areas can a sedentary soil be seen. In many cases where there appears to be a transition from solid rock to soil, the latter is found to contain some admixture of ice-carried erratic material. Soils are preponderatingly glacial or travelled. In the area covered by the Strathmore drift, especially round Ellon and Port Errol, one fancies that the underlying rock must be Old Red shales, sandstones and conglomerates; but this is exceptional, and there is usually in every travelled soil a large proportion of local material. There is much peat both at high and low levels.

D. Scenery.—With few exceptions hills under 2,000 ft. exhibit the flowing contours characteristic of glacial wear. From certain favourable view-points the hills of Banffshire and of Lower Deeside and North Kincardineshire look like the ground-swell of an ocean congealed after some prodigious storm: only rarely a craggy summit breaks the general monotony.

The fine scenic features of the Cairngorm and Lochnagar granite massifs are the direct results of glaciation—corries, corrie lakes, U-valleys, glen lakes (some now silted up), lateral and terminal moraines.

Most of the beauty spots in our river valleys are found where the streams, diverted from their pre-glacial courses through the infilling of these by drift, now flow in post-glacial rock-gorges, e.g. Brig o' Balgownie, Bridge of Alvah, Poldhulie Bridge (Strathdon). In this way the Don in the last ten miles of its course has been five times compelled to entrench itself in rock.

The lower Findhorn, which like the lower Spey has an abnormally steep gradient, has excavated in granite, schist and Old Red Sandstone a series of picturesque gorges, the ultimate cause of which may be rejuvenation by the same uplift that affected the lower Spey.

The major part of the coast-line of the four counties is rock-bound with fine and varied cliff scenery. It is interesting to note the contrast between the minutely fretted line of cliffs cut in schists with the more regular wall-like appearance of those cut in granite and in Old Red conglomerates and lavas. More Head of Gamrie (schist) rises steeply to a height of almost 500 ft.

IV.

ANIMAL LIFE OF NORTH-EAST SCOTLAND

BY

Prof. JAMES RITCHIE, M.A., D.Sc.

The Character of the District.—On December 2, some years ago, three guns out shooting for the day in Aberdeenshire are reported to have killed the following twenty-two kinds of animals : pheasant, partridge, woodcock, snipe, mallard, golden eye, pochard, tufted duck, ring-dove, brown hare, rabbit, curlew, golden plover, green plover, dunlin, little stint, purple sandpiper, turnstone, redshank, moorhen, water rail and coot. That typifies the character of the fauna (as well as of the human population)—the district may not produce many record bags, but it affords good mixed shooting. And the reason is a simple one, that within a limited area there is presented the utmost diversity of environment ; from muddy estuaries, frequented during the winter by many ducks and waders from Arctic regions, and shore-cliffs and sand-dunes tenanted by multitudes of breeding birds during the summer, to some of the highest mountains in the kingdom ; from the bare flat lands of Buchan to the primeval pine forests of upper Deeside. So that just as the district is a *multum in parvo* of scenic diversity, so the fauna represents a compendium of the fauna of the country as a whole. Nevertheless the North-east has some interests of its own.

Deeside, the Key to the North.—The north of Scotland is isolated from the south country by the Grampian Range and the mountains of northern Perthshire and south-western Inverness-shire, a barrier sufficient to check the spread of most low-country animals. But the barrier is breached by several passes which debouch upon the Dee valley, and it may be circumvented by way of the low land bordering the North Sea to the south of Aberdeen. By these passes every invading army of men has endeavoured to penetrate to the north, and by these passes the post-glacial animals, which already tenanted the first-inhabited lands to the south, must have pushed forward to occupy the north lands, left uninhabited upon the retreat of the ice-sheets. Since, from these far-off days till now, the coastwise and low-valley routes have offered the easiest and indeed the only available passage for most animals, it is within close mark of the truth to say that the ancestors of almost all the animals (excluding aerial forms) that now exist or have existed in northern Scotland must at one time or other have found their way thither across the waters of Dee.

In the earliest days of colonisation, in a late inter-glacial or in the

post-glacial period, the most impressive of the migrants—for there is no indication that the mammoth or the giant fallow-deer ever reached these northern parts—included reindeer (of which we recently found fragments of more than 900 antlers in a cave in Sutherland), the elk, largest of existing deer, the huge ancestors of modern red deer, and the great extinct ox, *Bos primigenius*. By these routes passed the lemming and the mountain hare, and the beaver may have found its way to the river Ness ; thus came the bear, the lynx, the arctic fox and the wolf, hard on the track of the grass-eaters.

Most of these early explorers of northern Scotland have long since disappeared ; we know of their presence only from bones recovered from the peat-mosses or from the kitchen middens of early human settlements, rarely from vague tradition. But it is characteristic of the wildness of the district that some of them lingered on long after they had become extinct in the south. In the underground ' eird-houses ' at Kildrummy on Donside have been found the bones of a small horse, a reminder that ' wild horses ' once roamed the forests, for even in 1507 it is recorded that a herd inhabited the Forest of Birse, though the chances are that they were the wild progeny of a primitive domesticated breed. Wolves were the last of the great carnivores to be exterminated. In 1010 King Malcolm III, on his return from the victory at Mortlach in Moray, is said to have been attacked by an enormous wolf in the Forest of Stocket, the site of which is now within the north-western boundary of Aberdeen city. At a much later date the plaint of John Taylor, the Water Poet of London, gives a vivid impression of the wildness of the country and its tenants, when in 1618, during a visit to ' the goode Lord Erskine ' at the ' Brea of Marr ' (Braemar), he relates : ' I was the space of twelve days before I saw either house, corn-field, or habitation for any creature, but deer, wild horses, wolves, and such like creatures, which made me doubt that I should never have seen a house again.' Before the seventeenth century had closed, however, the wolves had all but disappeared : in the north-east one was slain in Kirkmichael Parish in Banffshire in 1644 ; but persistent tradition relates that so late as 1743 the final survivor of the wolves of Great Britain was tracked and destroyed, after it had killed two children, in the wild hills between the rivers Findhorn and Spey.

The disappearance of the wolves is symptomatic of many, but not of all the changes which have made the present-day fauna of the district what it is ; and an analysis of the changes may afford a better understanding of the composition of the animal life of the district than could a catalogue of species.

Secular Changes and a Relict Fauna.—During the millennia which have passed since the ice-covering of the Glacial Age disappeared, the climate has been constantly changing. Its vagaries are revealed in any deep peat-bog, where successive layers of peat show, in the composition of their plant remains, the alternation of drier and moister periods, and from the oldest layers to the most recent, an amelioration of climate from Arctic and sub-Arctic to the temperate conditions of to-day. The Arctic period had a fauna of its own, of which Aberdeenshire contains some marine relics in its glacial clays, but although the Arctic fauna

which first peopled the uncovered face of the land has left few remains in the North-east, it may be assumed that the creatures whose bones we found recently in the north of Scotland—the reindeer, a great bear, lynx, arctic fox, lemming, mountain hare, ptarmigan, and others—were typical members of the first post-glacial fauna of the district.

That arctic association of animals has gone with the climate which brought it, but it has left an interesting relict fauna now confined, in our area, to the Grampian mountains : the Scottish mountain hare (*Lepus timidus scoticus*), the Scottish ptarmigan (*Lagopus mutus millaisi*), each of which assumes a white coat in winter, and the snow-bunting (*Plectrophenax nivalis*), the first family party of which in Britain was seen in the Cairngorms by MacGillivray in 1830, and which breeds only on the high mountains. Perhaps the stoat (*Mustela erminea*) is also a relict of the same fauna, for its winter change to white, which suggests an arctic habit, takes place regularly and completely only in the northern and higher part of its range in Britain.

The change of climate acted directly upon the inhabitants, repressing some, encouraging others, but its most evident effects have taken place indirectly, through the modifications it induced in vegetation, and in particular upon woodland.

Reduction of Forest Land and its Effects.—Peat-bogs throughout the district reveal the presence at one time of a great pine forest which covered the low-lying country and is represented in the Grampians up to a height of 2,400 ft. above sea-level, far above the present-day pine limit. A moist period followed its greatest development, when the recent beds of peat were formed and swamped much of what had been forest land. A good example was the peat-forest in the parish of Logie Coldstone, where dense masses of trees were found at a depth of 10 ft. in peat over an area of 100 acres, and where the trees seemed to have been blown over, for the trunks lay all in one direction, the effect of a gale playing upon woodland already sapped of its strength because of the marsh developing about its roots.

In later times man contributed to the disappearance of the woodland,[1] but even in the fourteenth century Aberdeenshire had at least eight great ' forests,' one of which was granted by King Robert the Bruce in 1324 to the Earl Marischal, a forerunner of the founder of Marischal College. Together nature and man have reduced the woods of the area to less than a tithe of their former extent, and so another great change has been imposed upon the character of the fauna. The red deer (*Cervus elaphus*), a woodland animal which in former days left its bones in peat-bogs throughout the low ground of the district, has been driven to the bleak and barren hills, and the relative poverty of food in its new habitat has been reflected in smaller size of body and less luxuriant antlers. Many denizens of the woods have become scarce or have been banished : the disappearance of the wolf has already been referred to ; the wild cat (*Felis silvestris*), so common a century and a half ago that 44 were killed between 1776 and 1785 about Braemar, has gone, the last

[1] An account of the factors which made for the destruction of Scottish forests will be found in the writer's *Influence of Man upon Animal Life in Scotland.*

on Donside having been killed at Alford in 1862, and on Deeside in Glen Tanar about 1875; the polecat or foumart (*Mustela putorius*), 30 of which were killed in 1863–64 by one keeper on a single Donside estate, has been absent from Aberdeenshire since about 1890; the pine-marten (*Martes martes*), having made last appearances in the low-lying part of the district, at Ellon in 1874 and in Fyvie in 1894 (probably as a wanderer from a distance), is extinct in the area, except perhaps in the woods of upper Strathdee.

It may be said that the disappearance of these creatures was due solely to the deliberate attacks made upon them by man and had no connection with the reduction of woodland; but the woods were their natural feeding ground and breeding ground, and about the same period woodland creatures against which man showed no special enmity were also dwindling in numbers or disappearing. Of the red squirrel (*Sciurus vulgaris*), the capercaillie (*Tetrao urogallus*) and the great spotted woodpecker (*Dryobates major*), early records within this district are scanty, but there is evidence here or in the neighbouring parts of Scotland that they became extinct respectively about the beginning of the nineteenth century, about 1770, and about 1840–50.

These are some of the extreme changes; we may take it that many lesser fluctuations and migrations followed upon each alteration in the amount and distribution of woodland.

The Present-day Fauna largely moulded by Agriculture.—Agriculture abetted changing climate in reducing the forests, for forest was turned into sheep pasture, and so agriculture shares in the responsibility for the changes just mentioned. But, besides, agriculture played an active part in the deliberate destruction of the beasts and birds which threatened the safety of the farmers' stock. Some of the beasts of prey we have already referred to; few are left, but destruction still goes on. In 1930, on upper Donside and Deeside, 89 foxes and 113 fox cubs were killed.

The larger birds of prey have suffered severely: between 1776 and 1786 seventy eagles were killed in five Deeside parishes; now, in spite of protective laws, only a few pairs of golden eagles (*Aquila chrysaëtus*) nest in the Grampians. In 1859, according to Dr. Adams of Banchory, the white-tailed eagle (*Haliaëtus albicilla*) was certainly not so rare as the golden eagle; now it is extinct in Scotland, though its memory lingers in this district in several 'Erne Heughs' and 'Erne Craigs,' which indicate its former nesting sites upon the coast cliffs. In MacGillivray's time, about the middle of last century, the kite or glead (*Milvus milvus*) was still 'not very uncommon in the upper tracts [of Deeside],' though it made up part of the 2,520 'small hawks and kites' killed in five Deeside parishes in 1776–86; but it also is extinct, for none has been seen since 1890.

Destruction is by no means confined to birds of prey: during 1930 the 'agricultural pests' reported killed to the Aberdeen County Council included 64,925 rooks and 3,563 eggs and 601 nests destroyed, 7,442 wood-pigeons as well as nests and eggs destroyed, 1,992 house-sparrows and 704 eggs, 1,108 starlings, 897 gulls and 145 eggs, 1,494 brown hares and 175 squirrels.

In another way agriculture has diminished and modified the fauna, for one of its most characteristic operations is the draining of the land; and the reduction of swamps and marshes, and, with the finer applications of draining and cultivation, even of the pools which once gathered and remained for weeks at a time upon arable land, has banished the habitats of many aquatic creatures. A striking illustration is afforded by the disappearance of the disease of ague in Aberdeenshire. Throughout the county ague was very prevalent during the eighteenth century, and after reaching a climax in the 'eighties, the number of serious cases fell off until by the middle of the nineteenth century the disease, as endemic, had all but disappeared. The majority of the ague cases were malarious, and the carriers of the infecting organism were mosquitoes which bred in ponds and pools. It is more than a coincidence that the decline of ague in Aberdeenshire corresponded with the period of agricultural activity which began towards the end of the eighteenth century, and was associated with drainage and the treatment of the land with lime, and so with the destruction of the breeding places of mosquitoes.

While agriculture was moulding the fauna in a negative sense by cutting off old-established denizens, it was also exercising a profound influence in increasing the numbers and range of other members of the fauna. The growing of cultivated crops for the sustenance of man and his domesticated stock, offered new food supplies to multitudes of wild creatures, so that encouragement was given to the multiplication of vegetarians amongst mammals, such as rabbits, hares, field-mice and voles, to seed-eating birds, such as sparrows and other finches, to the multitudes of insects which feed upon the roots, stems, foliage and seed of farm crops. Indeed it may be said that the farmer creates his own farm pests, and that, so long as his cultivation is successful, he is committed (short of extermination) to an endless warfare against a section of the native fauna which he has enlarged far beyond its natural or aboriginal proportions.

A secondary result was the increase of the creatures which feed upon the farm pests. A single example will illustrate the trend. Previous to 1850 the starling (*Sturnus vulgaris*) was only a non-breeding migrant in Aberdeenshire, and a rare one at that; since the 'sixties it has bred in increasing numbers, so that now it is abundant everywhere and remains all the year round; even within the boundaries of Aberdeen it has become a nuisance because of the roosting colonies of thousands which destroy shrubberies by their weight and their excrement. Now examination of the food of starlings caught in Aberdeenshire shows that they subsist largely upon the 'leather-jacket' larvæ of 'daddy-long-legs' (*Tipulids*), and beetles abundant in grass land; so that in particular the laying down of pasture has been an incentive to the increase of starlings, and the phenomenal increase of starlings throughout Scotland in recent years has coincided with the transference of much arable land to pasture.

Some Additions to the Native Fauna of Aberdeenshire.—In considering additions to the native fauna I am not thinking of those rare individuals which figure largely in local lists, but which are no more

than accidental wanderers with no chance of establishing themselves: such as the tropical loggerhead turtle (*Thalassochelys caretta*), which was found alive and sprightly in the salmon nets at Pennan in 1861, or the purple heron (*Ardea purpurea*) shot at Donmouth in 1872, the glossy ibis (*Plegadis falcinellus*) from Fraserburgh, or the American kill-deer plover (*Charadrius vociferus*) from Peterhead, all of which may be seen in the Natural History Museum of Aberdeen University, and there are many others. The real additions are creatures which, having been introduced, have become or threaten to become an integral part of the fauna of the district.

Some of these alien animals have been deliberately introduced and set free for commercial purposes or for sport. Such include the common rabbit, a native of south-eastern Europe, the first colony of which was established by the city fathers in the '*cunicularium de Abirdene*' on the links south of Donmouth and was flourishing in the sixteenth century. In the woods are pheasants from Asia, and, reintroduced after the native stock had disappeared, the red squirrel, which made its reappearance, from the south, in the Dee valley about 1855 and by 1875 had reached the north coast of Aberdeenshire, and the capercaillie, which first appeared on Dee in 1878 and by 1897 had reached the Deveron. The American musk-rat (*Ondatra zibethica*), a dangerous introduction, appeared on the banks of the Bervie in 1931, but seems since to have been exterminated in the district.

Many other now well-established creatures have been brought unwittingly to the district by commerce. The old black rat (*Epimys rattus*), originally brought by shipping from the East, occurred throughout Aberdeenshire until almost the middle of the nineteenth century (and occasionally individuals still crop up in the city), but even then it was being rapidly replaced by the brown rat (*Epimys norvegicus*) which reached Scotland in the first half of the eighteenth century, and the original home of which is also in Asia. Asia has given us the common cockroach of our houses, America a small red house-ant (*Monomorium*), the Douglas fir chalcid (*Megastigmus*), which destroys a goodly proportion of the seed of Douglas fir on Deeside, the American blight of our apple-trees, and the American meal worm in our porridge. From Europe have come the Mediterranean flour moth (*Ephestia*), some of the wood wasps (*Sirex*) and timber-beetles of our woods, the Hessian fly, destroyer of wheat crops, and the bed-bug, a gift of commerce to new markets.

But commerce has taken away as well as given. The sea-ports of the north-east of Scotland were for a time the mainstay of the whaling industry in Britain. Whaling companies were formed in Aberdeen before the close of the eighteenth century; in 1822 Peterhead with 16 whaling ships and Aberdeen with 14 followed Hull (40) in order of numbers, but by 1853 Peterhead, Fraserburgh, Banff and Aberdeen contributed 35 of the British whaling and sealing fleet of 55 vessels; in 1857, 42 out of 55. Whale-fishing from Aberdeen reached its zenith in 1823, when the 14 vessels captured 180 whales in the Greenland Sea and Davis Straits, but the captures declined and the loss of ships discouraged effort. In the *Aberdeen Journal* of October 13, 1830, we read: 'It is our painful

duty to-day to have to record most disastrous intelligence from the Davis Straits Whale Fishery. The number of ships this season was ninety-one, eighteen of which have been totally lost, many damaged besides; and the whole fleet have scarcely captured as many whales as would make up four good cargoes. . . . Seventy-five ships have been lost at the Northern Whale Fishery since the year 1819, when they first attempted to cross Davis Straits.' (And now trawling vessels from our ports pay regular visits to the one-time dangerous whaling grounds of the North.)

These disasters and the falling off of the numbers of whales and seals finally brought this fishing to an end; from 1844 to 1865, ten vessels in all were employed from Aberdeen, and of these five were lost; the last solitary whaling ship sailed from the port in 1865.

Thus the fauna, influenced now mainly by man and his doings, keeps changing, cut down and impoverished in some respects, in other ways added to in numbers and in kind, but never the same for two successive decades. It is a duty of the new natural history to trace in their detail and to interpret these fluctuations, of which we have given here but the crudest outline.

V.

THE FLORA OF THE NORTH-EAST

BY

ALEX. MacGREGOR, M.A.

Aberdeen spells granite, and the granitic soil of the North-east cannot boast of a rich flora. Our waysides and woodlands lack that wealth of striking flowers which favour a limestone soil and lend decorative effect to the lanes and hedgerows of southern England. It is true that nowhere in the south can be found a feast of beauty, such as the Dinnet Moor presents in July when the glory of the bell heather is the joy of the Nature lover and the despair of the artist. But the beauty of the bell heather is short-lived, and even the August brilliance of the higher moors soon fades to the uniform brown which is characteristic of heath for the greater part of the year. Nevertheless, the North-east has its compensations. When the wild flowers of the south are fading, and the grass of the Downs is withered, our countryside presents a freshness and a fairness which is a delight to holiday-makers seeking the quiet of rural haunts. Further, there are few areas which offer a greater variety of surface, from the land tilled by the labour of many hands to the wilds untouched by the hand of man, and none a greater variety of altitudes from the sea-level to the

summits of the Cairngorms—the highest mountain massif in our island. Such diversity bespeaks a flora which, if not particularly rich in the number of species, is at least exceedingly interesting and highly instructive.

Extent of Survey.—The area under review is roughly a parallelogram bounded on the north and east by the sea; on the west by the Findhorn; and on the south by the North Esk. The parallelogram includes the counties of Aberdeen, Banff, Kincardine and Moray—a total surface of approximately 3,300 square miles. On taking a general view of the geology of this tract, we find that igneous rocks, of which granite is by far the most common, predominate. In fact the granite of Aberdeenshire, Banff, and the northern third of Kincardine occupies a greater area than it does in any other part of similar extent in the British Isles. This extensive granite mass is flanked on either side by sandstone—the Trias and Old Red Sandstone of Morayshire and the Old Red of Kincardine.

Normally a very intimate connection exists between the flora of a particular region and the nature of its basic rocks, but for a large proportion of the lower levels of the North-east it does not seem possible to trace any definite relation between the rock masses and the vegetation on the soil which covers them. This is because the lower hills and moors, and what is now agricultural land, became the dumping ground for the débris left by retreating glaciers at the close of the Ice Age. Boulder clay of various kinds, mixed with erratic blocks of granite and gneiss, covers the natural rock to a considerable depth. The soil, therefore, except in the alluvial deposits, is not of great fertility. In spite of inferior soil, a wayward climate and a northern latitude, agriculturists have transformed this bleak and boulder-strewn wilderness into the finest farm-land in Europe. During the process the native flora of these lower levels was greatly reduced, and is now chiefly confined to the exposed seaboard, the woods, the peat-bogs, the sheltered river valleys, or the higher levels where agriculture is impossible.

Botanical Records.—The earliest records relating to the plants of the North-east are contained in the still extant MSS. (1765–70) of Dr. David Skene, a correspondent of Linnæus. Towards the close of the eighteenth century the study of botany received such a stimulus that we find the nineteenth opening with quite a school of zealous investigators in the area. The year 1836 must have been its *annus mirabilis*, for that one year produced (1) Part I of Dr. Murray's *Northern Flora*, (2) Dr. Dickie's *Flora Aberdonensis*, and (3) Surgeon Cow's *Flora of Aberdeen*, the last printed but never published. Next came (4) Dr. Gordon's *Collectanea to the Flora of Moray* (1839); (5) Paul H. Macgillivray's *Flora of Aberdeen* (1853); (6) Prof. William MacGillivray's *Natural History of Deeside*—issued posthumously by order of Queen Victoria; and (7) Prof. Dickie's *Botanist's Guide to the Counties of Aberdeen, Banff and Kincardine* (1860). The present century brought (8) Prof. Trail's *Flora of Buchan* (1901); (9) Prof. Craib's *Flora of Banffshire* (1912); and (10) Prof. Trail's *Flora of the City Parish of Aberdeen*, published (1923) as a memorial volume. Articles on flowering plants, galls, fungi, mosses, etc.—some of which have also been published in pamphlet form—have from time to time appeared in the *Scottish Naturalist*, *Annals of Scottish Natural History*,

The Deeside Field, and in the Transactions of various societies. For the last twenty years of his life Prof. Trail had been compiling the results of personal investigation into the distribution of plants over a wide area in the north of Scotland, and all interested in botanical research will regret that he did not live to publish what would have been an invaluable contribution to scientific study. The regret is all the deeper because no Flora of Aberdeenshire has been issued since the appearance in 1860 of his predecessor's *Botanist's Guide*, and because the probability is that no single botanist will ever gain that intimate knowledge of the flora of the North-east which fifty years of field-work enabled Prof. Trail to possess.

The Sea Coast.—No part of our seaboard has a greater reputation as a botanical resort than ' the cliffs of St. Cyrus.' The volcanic rocks of that neighbourhood decompose into a light warm soil extremely favourable to the growth of a number of plants which here reach their northern limit or are rarely found north of Bervie. The cliffs and the close turf below them provide *Viola hirta*, *Silene nutans*, *Dianthus deltoides*, *Hypericum perforatum*, *Astragalus danicus*, *A. glycyphyllos*, *Vicia lutea*, *Lathyrus sylvestris*, *Trifolium striatum*, *Campanula glomerata*, *Lamium hybridum*, and many other interesting plants. Den Finella, in the same neighbourhood, is also worthy of a visit. Though inferior to St. Cyrus in number and variety of species, the rocks of Muchalls have, in addition to many commoner plants, several very local ones such as *Valerianella olitoria*, *Mertensia maritima* and *Artemisia maritima*.

From Aberdeen to the Sands of Forvie north of the Ythan the coast-line is flat and consists of sand-dunes with their characteristic flora, about which we may add that ' *Viola Curtisii* is the most common pansy there, though not recorded for the East Coast of Scotland until 1885.' (Trail Memorial Volume.) North of the Ythan a large granitic mass at Peterhead covers an area of 46 square miles and forms the rocky coast-line for several miles. Thrust like a knotted shoulder in the teeth of the north-east winds, these rocks support but a scanty vegetation. The Bullers of Buchan, however, shelter *Sedum roseum*, and those facing the Moray Firth at Aberdour and Gamrie yield *Saxifraga oppositifolia* and several rare *Hieracia*. From Troup Head to the mouth of the Spey rocky headlands and curving bays lined by fixed sand-dunes alternate with an almost uniform regularity, and present few features of botanical interest.

Immediately west of the mouth of the Spey lies a marshy area called the Leen of Garmouth, which the Rev. George Birnie, B.D., of Speymouth, considers the richest floral tract of a square mile he has ever traversed. From it he has gathered about 400 species, among which are an unusual proportion of comparatively rare plants such as : *Ranunculus sceleratus*, *Teesdalia nudicaulis*, *Ornithopus perpusillus*, *Œnanthe crocata*, *O. fistulosa* and *Salicornia europæa*. Specially noteworthy is the occurrence on the adjoining shingle of *Jasione montana*—its only station on the east coast of Scotland. Observed there in 1830 by the Rev. Dr. Gordon of Birnie, Morayshire's most distinguished naturalist, it is more than maintaining its ground. On the coast between Lossiemouth and Burghead grow *Scilla verna*, *Ligusticum scoticum*, *Astragalus glycyphyllos* (very rare for this latitude), *A. danicus*, *Carduus tenuiflorus* and *Euphrasia curta* var. *glabrescens*.

The Culbin Sands.—From the mouth of the river Findhorn the Culbin Sands—perhaps the most extraordinary physical phenomenon in Scotland—extend westward for more than six miles with a width varying from one to almost two miles. Here great accumulations of inblown sand have been piled up into enormous mounds, some over 100 ft. in height. These larger sand-hills, which are entirely destitute of vegetation, are continually on the move as the prevailing westerly winds drive the fine surface sand farther and farther east. But between these barren hills and the sea, and in an ancient bed of the Findhorn, which formerly discharged into the Firth three miles west of its present mouth, lie shallow lochs and moist hollows where a vegetation of intense interest to the ecologist exists. Since the estate of Culbin—once the 'Granary of Moray'—was overwhelmed by drifting sand in 1694, man's interference had, until recently, effected little change in the vegetation. Now, however, the Forestry Commissioners, who have charge of the Culbin Sands area, are endeavouring to fix the barren dunes, by planting several hundred acres with *Ammophila arenaria*, in addition to planting Corsican pine and other conifers on the dunes as well as in the hollows. If, by sustained effort, the Commissioners succeed where hitherto individual efforts have failed, many of the rarer plants will in time disappear and the flora will lose much of its individual character and present attraction.

Fortunately a very thorough ecological survey—the only one undertaken in the North-east, so far as we are aware—was made in 1923 by Mr. E. I. A. Stewart and Dr. Donald Patton of Glasgow. The results, the value of which will increase with the years, were published in the *Transactions of the Botanical Society of Edinburgh*, vol. xxix, and in the *Botanical Exchange Club Report* for 1923. The value of the survey is greatly enhanced by reference to the important part which certain cryptogams, mentioned by name, play in the fixation of the sand. These mosses and lichens not only occupy open spaces on the Ammophila-topped mounds, but by their closely interwoven shoots act as effective sand-binders. During their investigations Messrs. Stewart and Patton discovered in an artificial dam *Hottonia palustris*, a plant new to Scotland. To their published list of 250 phanerogams at least 15 fall to be added along with a fourth fern, *Botrychium Lunaria*. In the list no fewer than nine species of orchids occur, including *Goodyera repens*, growing practically at sea-level, and one of the rarest of the orchid family—*Coralorrhiza trifida*—discovered as a new county record in 1910. Though at low tide the mouth of the Findhorn is only a few yards wide, yet there is a striking contrast between the flora of the right bank and that of the Culbin Sands area on the left. Suffice it here to say that some 30–40 species grow on the right side which have not been recorded for the corresponding area on the left. Of these the more important are *Thalictrum dunense*, *Ranunculus Baudotii*, *Sisymbrium Sophia*, *Malva rotundifolia*, *Ligusticum scoticum*, *Carduus tenuiflorus*, *Erythræa littoralis*, *Volvus Soldanella*, *Elymus arenaria*.

Deeside.—As the Trail Memorial Volume includes comparative information on the distribution of plants in the seven parishes adjacent to the city parish, no further reference need be made to the flora of the immediate neighbourhood of Aberdeen. Turning inland we note that

though a considerable part of Deeside is floored by gneisses and schists, the Dee drains a more extensive area of granite than any other British river. For the most part the soil of Deeside is light and sandy, and better suited to sylviculture than to agriculture, while that of the moors and hills is more favourable to the growth of heather than of grass. One version of a familiar couplet—

> ' The River Dee for fish and tree,
> The River Don for horn and corn,'

pithily expresses the greater agricultural richness of the valley of the Don. The Dee valley, particularly the upper portion, is well wooded, but except for the Ballochbuie Forest on the Balmoral Estate, and the giant pines which still survive in Glen Lui and Glen Quoich, the woods are all plantations or have grown from seed naturally sown by planted trees. Extensive felling of timber, during and since the war years, has led to a great increase of secondary moorland, and a marked difference on the plant life of these areas. Fortunately all but a few of our characteristic woodland flowers thrive on heath and either survive there or in patches of standing timber, whence they subsequently spread to new plantations.

The most interesting of our Deeside woodland plants are the *Pyrolas* and three species which are often associated—*Linnæa borealis*, *Trientalis europæus* and *Goodyera repens*. The *Goodyera*—as much a lover of old pine-woods as the Crested Tit—seldom survives the removal of overhead cover, and has thus a more limited range than the others. Repeated search has failed to locate it west of Ballochbuie Forest or at a higher elevation than about 1,000 ft. Of the wintergreens, *Pyrola secunda*, *P. media* and *P. minor* are widely diffused, though the first is seldom found in the lower parts of the valley. A new station for *Moneses grandiflora* (1931), the first for the Braemar district, is probably the only one in the North-east outside Morayshire where this rare and beautiful wintergreen is still growing.

The limestones of Braemar account for the richer flora at the base of Morrone, where birch and poplar replace pine-woods. There the botanist will find plants characteristic of moor, marsh and meadow as well as woodland. He will further recapture spring even after midsummer, for *Orchis mascula*, *Anemone nemorosa* and *Caltha palustris* may be found in flower in July, while the variety *minor* of the last mentioned lights up the higher rills even in August. The flowering of *Ranunculus ficaria* at 2,500 ft. on the southern slope of Little Craigandal (late July 1928) is worthy of note not because it was a new record for Braemar, but because the elevation is 2,000 ft. above the highest of Dickie's records. In Morrone woods along with three wintergreens grow *Trollius europæus*, *Arabis hirsuta*, *Vicia sylvatica*, *Sanicula europæa*, *Habenaria conopsea*, *H. albida*, *H. viridis* and *Listera ovata*, while *Malaxis paludosa*, *Listera cordata*, *Orchis incarnata* and *Tofieldia palustris* grow on the adjoining moors.

The Cairngorms and Lochnagar.—Since George Don, that pioneer discoverer of our Alpine flora, first explored ' with a botanical eye the lofty mountains of Cairngorm and the great hills of that neighbourhood ' in 1801–2, Braemar has year after year been the Mecca of distinguished

botanists from far and near. Two of the three districts richest in our rarest Alpines lie within comparatively easy access—the Cairngorms themselves, and the Lochnagar group of mountains with the hills and glens lying on the Aberdeenshire-Angus border. Though neither is so rich as Breadalbane, both areas offer great possibilities because of their wider range of extent and altitude, and because they have been much less thoroughly searched. The Cairngorms alone cover an area of about 300 square miles, and extend for miles as a great elevated plateau of granite having a mean elevation of 3,800 ft. On the summit of this plateau and in the corries which gash its flanks, particularly those facing north or north-east, grow the hardiest of our Alpine gems. As, with a few exceptions, all these are found growing within the Arctic Circle they are strictly 'Arctic-alpine.'

The flora of the mountains consists of three different groups of plants: (1) Those which are of universal range (from the sea-level to the summits of the highest mountains), like *Empetrum nigrum* and *Vaccinium myrtillus*; (2) those which inhabit our rocky coasts and the high corries but not intermediate localities, like *Sedum roseum* and *Saxifraga oppositifolia*; (3) those which normally grow above 1,000 ft., including a few which do not descend below high levels, like *Juncus trifidus* (above 2,200 ft.) and *Luzula arcuata* (above 3,700 ft.). Among the first group are many plants like *Alchemilla* and *Euphrasia*, of which all the mountain forms were formerly classified under the trivial name of *vulgaris* or *officinalis*. As the result of more critical study, and of comparison with continental species, many upland forms now rank as species or sub-species. Though it is difficult to explain why, it is well known that certain corries and localities like Glen Callater, with its adjoining Corrie Kander, and Little Craigandal are far richer in Alpine species than others which seem equally well suited for them. A rocky slope on Little Craigandal lying at an elevation of 2,400–2,800 ft., where Prof. Balfour discovered *Astragalus alpinus* in 1842, is richer than any similar area north of the Dee.

In Volume I of the *Cairngorm Club Journal* Prof. Trail gave a list of 'The Flowering Plants and Fern Allies of the Cairngorms,' which contains all those likely to be met with apart from critical species recently discovered. In the *Annals of Scottish Natural History* for 1908–9–10 Mr. Frederick N. Williams discusses 'The High Alpine Flora of Britain' found at or over 1,000 metres (3,280 ft.), but it is necessary to explain that as he deals with all species recorded for that zone of altitude, he includes many species of universal range and not considered strictly Alpine. As an example of how species of the British type decrease with altitude we may note that on the summit of the Coyles of Muick (1,956) we find 12 out of a total of 19; on Mount Keen (3,077) 3 out of 8; while on Ben Macdhui (4,296) all seven—*Silene acaulis*, *Saxifraga stellaris*, *Salix herbacea*, *Luzula spicata*, *L. arcuata*, *Carex rigida*, *Festuca vivipara*—are of the Highland type. Among the rarer Alpines of the Cairngorms are *Sagina alpina*, *S. Boydii*, *Saxifraga nivalis*, *S. rivularis*, *S. cæspitosa*, many *Hieracia*, and several rushes, sedges and grasses. In addition to these *Salix lanata* and *S. reticulata* grow in Glen Callater and Corrie

Kander, while *Lactuca alpina*, the *Sonchus cœruleus* discovered by Don in 1801, is perhaps the most striking Alpine from Lochnagar itself.

Donside.—As we have already hinted, the valley of the Don consists largely of arable land, and its flora will thus be of less interest and variety than that of Deeside. There are areas, however, like Scotston Moor, Paradise Woods, Monymusk, the Howe of Alford and the higher levels of Corgarff which furnish a number of local plants. On Scotston Moor, which lies about two miles north of the Old Bridge of Dee, grow *Parnassia palustris*, *Sedum villosum*, *Drosera anglica*, *Pyrola media*, *P. minor*, *Utricularia minor*, *U. intermedia*, etc., with a patch of *Linnæa borealis* in an adjoining wood. An almost forgotten botanist of the North-east, Prof. James Beattie, of Marischal College, a nephew of the poet Beattie, was in 1795 the first discoverer for Britain of *Linnæa*, which he recorded for 'Inglismadie, Mearnsshire' (Kincardine).

From Corgarff, Upper Strathdon, are recorded *Rubus saxatilis*, *R. Chamæmorus*, *Alchemilla alpina*, *Sedum villosum*, *Crepis paludosa*, *Gnaphalium supinum*, *Arctostaphylos alpina*, *Pyrola secunda*.

In his *Flora of Buchan* Prof. Trail includes all the parishes between the Ythan and the Deveron, and as all the records are based on his personal observations, there is little need for further reference to an area so thoroughly and so authoritatively examined. A few of the rarer or more local species are *Ranunculus sceleratus*, *Cochlearia danica* and *C. greenlandica* (Slains), *Stellaria nemorum* (Alvah), *Sagina ciliata* (very local), *Rosa hibernica* (rare), *Saxifraga hypnoides*, *Galium Mollugo*, *Hieracium Schmidtii*, *H. rigidum*, *H. corymbosum* (scarce and very local).

Banffshire.—The two extremes of Banffshire—the coastal area and the upland section culminating in the Cairngorms—have already been dealt with, and as its Flora (1912) is comparatively recent, the middle portion, which is mainly agricultural, requires little comment. Two names intimately connected with the botany of the area, however, deserve special mention in addition to that of the late Prof. Craib, viz. Thomas Edward, the Banffshire naturalist, many of whose records of the rarer species are referred to in the Flora; and Mr. John Yeats, M.A., for many years Secretary of the Banffshire Field Club. The latter crowned a long career as a field botanist by finding, when over 80 years of age, the extremely rare *Saxifraga Hirculus*.

Banffshire has no main river valley to itself, as it shares the Deveron with Aberdeenshire, and the lower Spey with Morayshire, though it can lay full claim to the Avon, the chief tributary of the Spey. The high ground near the confluence of these two rivers culminates in that fine isolated hill, Ben Rinnes, on whose upper slopes occur such Alpines as *Loiseleuria procumbens*, *Rubus Chamæmorus*, *Saxifraga stellaris*, *Epilobium anagallidifolium*, *Gnaphalium supinum*, *Salix herbacea*.

Morayshire.—Geologically Morayshire falls into two divisions—a plain in the north of Old Red Sandstone and Trias, overlaid with glacial deposits, and a hilly region in the south composed of metamorphic rock, chiefly schists. The seaboard plain, known as the 'Laich of Moray,' is famous for the mildness of its climate and the richness of its alluvium. With a low rainfall—at Forres occasionally under 20 in.—and a high

maximum of sunshine, it presents a marked contrast to the corresponding area east of Spey. As few of the Morayshire hills rise above 2,000 ft., its Alpines are limited to those grown from seed washed down the river valleys. By way of compensation the flora of the 'Laich' contains several species seldom found north of the southern counties of Scotland, and includes some 57 not recorded in the *Flora of Banffshire*.

As the death of Dr. Gordon precluded the publication of a contemplated second edition of his *Collectanea*, it is of interest to report that a *Flora of Morayshire* containing almost 1,000 species has been compiled under the auspices of the Moray Field Club, with its former secretary, Mr. J. J. Burgess, M.A., as editor.[1] His collaborators are Rev. George Birnie, B.D., Speymouth, who contributes a chapter on Mosses, and Mr. Peter Leslie, M.A., B.Sc., formerly Lecturer on Forestry in Aberdeen University, who is responsible for Conifers, Fungi and Algæ. Mr. Birnie had previously issued a Catalogue of Mosses for Vice-County 95, and the late Dr. Keith, Forres, several lists of local Fungi, but as little else dealing with the botany of Moray has been published in permanent form, the new volume should prove a welcome addition to the number of county Floras. It is hoped that the new *Flora*, for which the Prime Minister has written a foreword, will be published this year.

Some of the rarer species found in that part of the Spey valley within Morayshire are *Pyrola secunda*, *P. media*, *Carex aquatilis* (Grantown); *Arabis hirsuta*, *Agrimonia Eupatoria*, *Pimpinella Saxifraga*, *Galium boreale* (Craigellachie); *Linnæa borealis*, *Ulex minor*, *Impatiens parviflora*, *Atropa Belladonna*, *Listera ovata*, and the rarest of the wintergreens, *Moneses grandiflora* (Fochabers). Found there and near Brodie Castle (1792) for the first time in Britain, it still survives in three or four localities.

Though entirely a Morayshire river, the Lossie has few places of botanical interest apart from Loch Spynie and the neighbourhood of Elgin. The area farther west is drained by the Findhorn. Unrivalled for the beauty of its scenery, that part of its valley which extends for seven or eight miles from the point where the river crosses the county boundary is the paradise of the artist and the nature lover. Nowhere in the county are the flowers so massive, their bloom so delicate, and their foliage so rich as on the banks of the Findhorn. Cothall, with its belt of limestone, and the woods adjoining, have long been known for such interesting plants as *Geranium sanguineum*, *Saxifraga aizoides* (at Sluie for 100 years), *Agrimonia Eupatoria*, *Circæa alpina*, *Sanicula europæa*, *Eupatoria cannibinum*, *Carlina vulgaris*, *Lithospermum officinale*, *Neottia nidus-avis*, *Carex pendula*, *Melica uniflora*, *Equisetum hyemale*. The Greshop Woods lower down yield *Sisymbrium Sophia*, *Stellaria nemorum*, *Malva sylvestris*, *Adoxa Moschatellina*, *Echium vulgare*, while across the river in Dyke *Monotropa Hypopitys* has twice been found in the beech woods.

Enough has been written to prove that the flora of Moray contains many species seldom found north of the Border counties of Scotland, and that the 'Laich of Moray' has a rich soil and a favoured climate. If emphasis were needed, we can point for confirmation to Elgin Cathedral and other

[1] Mr. Burgess died (February 28, 1934) since the above was written.

ecclesiastical buildings, now, alas, in ruins, for the monks of old had a keen eye for fertile lands as well as for rural beauty. At Elgin, Pluscarden, Spynie Palace, Kinloss Abbey or elsewhere *Chelidonium majus*, *Hyocyamus niger*, *Atropa Belladonna*, *Marrubium vulgare* and *Ballota nigra* survive as reminders of the monks' healing art and as relics of their herbal gardens.

VI.

FORESTRY

BY

PROF. A. W. BORTHWICK, O.B.E., D.Sc., F.R.S.E.

FORESTRY in the North and North-east of Scotland covers a wide and diversified area. The geological conditions, mountains, lochs and rivers, have given rise to very varied types of soil which change, mingle and separate over comparatively small areas. The three northern counties stretch from sea to sea, and indeed, leaving out county boundaries, so does the whole area under consideration. It therefore embraces climatic conditions typical of the east and west coasts. Exposure, elevation, climate and soil may therefore be expected each to play its part in the development and types of forest to be found in this region. From historical accounts and the existing scattered remains of the original forest, as well as of the roots and trunks of trees, especially the Scots pine, in peat mosses, it is suggested that the Sylva Caledoniæ at some time extended from the Moor of Rannoch in the west on the confines of the shires of Perth, Argyll and Inverness, eastward to the remaining woods of Mar at the sources of the Dee and the Don, in West Aberdeenshire, and thence down the ridge on the northern part of the county of Mearns, which forms the southern boundary of the river Dee. Farther to the north, the remains of the primeval pine forest in the peat indicate that it extended much nearer to the sea, covering the low lands of Aberdeen and Moray. Along the shores of the Moray Firth no remains exist at the present day above ground on the slopes of the mountains facing the sea ; but in the massive Cairngorm mountains extensive remains are found in the glens and valleys of the river Spey and its tributaries. Other accounts say that all the territory north of the Forth and Clyde was covered by a vast forest, the forest of the Caledonii. The name 'Caledonii' means 'the people of the coverts,' and applied to the inhabitants of the forest rather than to the territory which it occupied. In later days the term was applied in a general way to the whole of Scotland. The native forest was not entirely composed of pine, but contained an admixture of oak, birch, willow, alder, hazel and others.

The early destruction of the forest began in the time of the Romans. It was found to be impossible to drive out the inhabitants without destroying the forest, which was their natural fortress. The destruction of the forest and the felling of trees to make roads was therefore carried out on a large scale, to reach the inhabitants in their sylvan retreats. It is said that the Roman General Severus lost no fewer than about 50,000 men in destroying the forests and endeavouring to overcome the physical barriers of the country. Historians seem to differ in opinion as to the presence or absence of extensive forests in the days of old, but surely we can rely on the numerous remains of large trees so commonly found all over the territory of the ancient Sylva Caledoniæ as definite and satisfactory proof of the vast extent of the natural primeval forest.

The work of forest destruction was not confined to military operations alone. In feudal times the population was led to believe that the growth of timber was an obstacle to the production of food, and wanton destruction of the forest was carried to excess. The barons of the time seem to have placed no restraint on this work of desolation, and by the fourteenth century Scotland was mostly devoid of timber except in the remote glens and other inaccessible places.

The bleak and desolate condition of the country began to engage attention in the time of James I, who forbade the cutting down of trees. In 1457 the parliament of James II enacted that the king charge the tenants of all his freeholds both spiritual and temporal, that they plant woods and trees and make hedges and sow broom. In 1503 the parliament of James IV enacted that 'every Lord and Laird, make them to have parks with deer, stanks, cunningares (rabbit warrens), dowcotts (dove-cots), orchards and hedges and plant at least one acre of wood.' In 1535 the above is ratified by the parliament of James V, and in addition, every man having 'an hundred pounds land, of new extent,' is required to plant three acres and to make hedges and haining, and 'that the tenants of every merk of land plant a tree.' In 1668, in the reign of Charles II, further laws were enacted regarding the planting and tending of oak and other trees.

In this connection it may be of interest to recall that in 1616, after one of these numerous insurrections fomented by the Macdonalds, Lords of the Isles, the leading island chiefs were bound over at Edinburgh amongst other things to build 'civil and comlie' houses and to repair those that were decayed and to have 'police and planting about them.' It is perhaps interesting to speculate as to what might have been, had the warlike western chiefs succeeded in conquering and overrunning the North-east of Scotland in 1411, led by Donald, Lord of the Isles, who claimed the Earldom of Ross. His claim was refuted by the Duke of Albany, who informed the chief that if he wanted Ross he must fight for it. Donald's reply was to come east with a large army of Highlanders. He overran and ravished all Moray, and then set out south, with the intention of sacking and burning Aberdeen. At Harlaw, twenty miles north of Aberdeen, he was met by the Earl of Mar with a small but well-disciplined force of armoured burgesses. Donald and his army descended on them like a mountain torrent, but the wild charges and rushing waves

of the impetuous islanders made small impression on the feudal force in armour, and after an all-day fight Donald had to retire to the Highlands. At this remarkable battle the menace and power of the western chiefs was forever broken as far as the North-east was concerned. Had Donald succeeded in overcoming and subduing Ross and the North-east, the enactments of James I and his successors for the planting of woods and trees might never have been made. Thus Aberdeen can claim its share for the part it played in early history of forestry development.

The percentage of woodland area in the North-east of Scotland, especially in the counties of Elgin, Aberdeen and Kincardine, is, along with the four counties in the South-east of England and Monmouth, the highest for Great Britain. The three Scottish counties mentioned, and including Banff, show a percentage of felled woods well above the average for the rest of the country. This indicates that with the area of standing woods, together with that which was felled principally during the war, a very high proportion of land is under afforestation in the North-east of Scotland.

The climate in the north, with few exceptions, is sufficiently mild, contrary to what is generally supposed, to admit of the cultivation of a surprising number of exotic species of trees and the production of really fine hardwood timber.

There are many extensive wooded estates in the North and North-east of Scotland, but the space we are allowed will only permit of a short reference to a few. The valleys of the Dee and Don and the Spey, each with its tributaries and side glens, are richly clothed with woods and forest which have long been famous for the excellence of their timber. For miles along the lower valley of the Dee the road passes through many small residential estates with well-laid-out shelter belts, and parks with single or massed groups of ornamental trees and shrubs and well-kept avenues and hedges. These greatly enhance the natural beauty of the valley. Interesting examples of trees and woods are to be seen at Hazelhead, Countesswells and Craibstone, all within a short distance of the town. Farther afield in the upper valley of the Dee, on the Hill of Fare and in the woods of Craigmyle and Learney, pine and larch cover extensive ranges of hills and slopes. In the districts of Aboyne, Glentanar, Ballogie, Balfour and Finzean, the Scots pine and the larch grow particularly well. These and neighbouring estates can not only show coniferous forests of the highest economic quality, but also hardwoods of fine growth and form. The Ballater district has also long been famed for its woods and forests. The Royal estate of Balmoral is a model for both arboriculturalists and sylviculturalists. The woods and plantations have been laid out and tended with the highest skill and all that is best in forest management. The Castle is situated on the right bank of the river, and the policies extend from below the Manse of Crathie right up to the old primeval forest of Ballochbuie. Steep rocky slopes on each side of the river have been clothed, since Balmoral became a Royal residence, with plantations of forest trees of many kinds, indigenous and exotic. The plantations of various ages and species mingle harmoniously among themselves and with their surroundings

and form a fine background of wooded slopes which rise in the direction of 'Dark Lochnagar.' The old forest of Ballochbuie contains many grand and picturesque trees of the finest type of Scots pine. Their clean, straight, cylindrical stems of great girth contain timber of the highest quality. From the Ballochbuie forest, in earlier times, came many trees for shipbuilding and other purposes for which large-sized timber of the finest quality was required.

On the Glentanar estate, the old forest of that name covers an extensive area, rising high on the slopes of the glen or the valley of the Tanar and its tributaries. Birkhall, Glenmuick and Abergeldie are also well-wooded properties. The policies and woods of Invercauld, on the left bank of the river, contain some fine examples of hardwoods and coniferous plantations. Natural woods of oak, birch, rowan, alder, aspen and others, so typical of many parts of the valley and associated with artificial woods of pine and larch, on the Mar estate, continue tree growth from the Linn of Dee to the wooded part of the old primeval forest of Mar.

A striking feature in many parts in the upper valley of the Dee is the high elevation at which good timber can be grown. The Kirktown of Braemar stands at an elevation of about 1,000 ft. above sea-level, but the timber line extends many hundred feet beyond that elevation. On the Mar estate good larch over 100 years old has been grown at 1,900 ft., which is far above the timber line for most of the country.

For several miles above the picturesque Brig of Balgownie the river Don is flanked with finely wooded slopes, which terminate in the ornamental grounds of Seaton House. Among the wooded properties near Aberdeen, Parkhill is outstanding. On this estate, the luxuriant vigour and growth of the younger plantations, and the fine form and development of the older trees, bear testimony to the suitability of soil and climate and to the care and skill which has been given to their management. A more pastoral type of country intervenes until Kintore is reached, where woods and plantations again prevail. Among the more important wooded estates higher up the valley are Monymusk and Castle Forbes. In the extensive plantations of Monymusk the Scots pine, larch and spruce predominate. The old Garden of Paradise contains a rich store of arboreal treasures. Along with the fine old larches, contemporaneous, it is said, with those planted at Dunkeld in 1743, are fine specimens of pine, spruce, silver fir and yew, together with splendid individual trees of oak, beech, ash, elm, sycamore and other hardwoods. The Castle Forbes woodlands are extensive, thriving and well managed. On Kildrummy there are some extensive plantations of Scots pine and larch and Douglas fir of good quality. At Strathdon, the head of the valley, there are interesting woods and plantations on Castle Newe, Edinglassie and Candacraig.

To the south of Aberdeen, the estates of Durris, Drumtochty, Fettercairn, Fetteresso and others bear eloquent testimony to what can be done successfully in this part of the country under good forestry management.

The celebrated forest of Glenmore surrounds Loch Morlich, which is the source of the Durie, a tributary of the Spey, which drains Rothie-

murchus and Abernethy. Except on the west, the forest is sheltered on all sides by lofty mountains. The trees, as the history of the forest shows, have always been of fine growth, and the timber line extends up the mountain sides from 1,100 ft. to 1,400 ft. In the statistical account of Scotland it is recorded that the Duke of Gordon sold his fir woods at Glenmore in the Barony of Kincardine for £10,000 sterling to an English company. The activities and busy scenes associated with the felling and floating of the timber down the Spey, and the ship-building at Speymount which sprang into existence, are vividly described by the older writers. The inscription on a memorial plank cut from a tree of the forest at that time and which still stands in the entrance hall of Gordon Castle, gives clearly an idea of the magnitude of the enterprise.

The inscription is as follows : ‘ In the year 1783, William Osborne, Esqr., Merchant of Hull, purchased from the Duke of Gordon, the Forest of Glenmore, the whole of which he cut down in the space of 22 year, and built during that time, where never vessel was built before, 47 sail of ships of upwards of 19,000 tons burthen. The largest of them of 1000 tons and three others but little inferior in size, one now in the service of His Majesty and the Honble. East India Company. This undertaking was completed at the expense (for labour only) of about £70,000. To His Grace, the Duke of Gordon, this plank is offered as a specimen of the growth of one of the trees in the above forest, by His Grace’s most obt. servt., W. Osborne, Hull, Sept. 26th, 1806.’

Various accounts show that the forest began to regenerate itself naturally after the trees had been cut down, and in 1914 a new crop of a fine type of Scots pine of the best quality had matured. A crop of inestimable value to the country at that time.

There are extensive forests in the glens and valleys of the river Spey and its confluents. Scots pine and larch are of specially good growth and form in this part of Scotland. Natural regeneration is the outstanding feature in forestry management in Strathspey. Enclosure at the right time and the cessation of grazing is followed by an abundant appearance of natural seedlings among the heather. The Seafield, Rothiemurchus, Orton and other estates are famed for the magnificence of the Scots pine, which grows and flourishes in extensive forests, in this its apparent optimum locality. Altyre, Darnaway and Gordon Castle are noted for the excellence of the Scots pine and other timbers produced in their well-managed woods.

The county of Ross presents a great variety of surface ; mountain, glen, river, loch and moor make up a general landscape of exceeding charm and grandeur. Many tracts of fine arable land and pasture occur throughout the county. With one or two exceptions no large continuous wooded areas exist, but numerous small woods, shelter belts and clumps of trees abound, near and around mansion houses and farm steadings. Hardwoods and Conifers of many kinds thrive well. The peninsula of the Black Isle, bounded by the Moray, the Beauly and the Cromarty Firths, presented at one time, we are told, a bleak and dreary landscape, heath-covered and so lacking in pasture that it was said a goat could

not live over five acres on it. Many woods, shelter belts, strips and clumps of trees now exist which afford considerable shelter to dwellings, arable lands, stock and pasture.

The Novar estates, for the extent and quality of their woodlands and their excellent management, are easily the best in Ross-shire and indeed stand high among the woodland estates of Britain. That part of the county known as Easter Ross, which comprises the lower lying districts along the shores of the Cromarty Firth, was at one time of little value as it contained many small lochs, bogs and swamps. Drainage and land reclamation, together with extensive planting, have combined to ameliorate the climate and to convert this relative waste into a land of green fields, flourishing woods and pleasing landscapes.

Wester Ross is mainly a region of mountain and sheep grazings, and natural woods of birch mingled with the remnants of some fine old primeval pine. Nevertheless, many plantations of Scots pine and larch have been established with success on many estates in this part of the country. Some of these are of considerable extent, as on the Gairloch and Braemore estates, where Scots pine, larch, spruce and other conifers have grown well. The Braemore woods were planted round about the year 1870, and yielded much valuable material during the war.

In the Hebridean Islands shelter and soil are the main problems. There are, however, many fine grown trees, woods and plantations of different kinds which show that these difficulties can be overcome by skill and perseverance.

Research.—One of the biggest problems at the present time in forestry is how to deal successfully with the large tracts of peat areas and difficult planting ground in the Highlands and elsewhere.

Much valuable knowledge has been gained by the investigations and experimental work carried out since 1892 by Sir John Stirling Maxwell at Corrour, in the south-east of Inverness-shire. The plantations lie around the north-east half of Loch Ossian and are all above the 1,250 ft. contour. The first plantations were confined to parts which were not supposed to require drainage. The results were not altogether satisfactory. Nevertheless, close observation and study of these plantations provided useful and promising lines for further experiments in methods of planting, choice of suitable species, age and size of plants to use, planting distances, the use of pioneer and nurse species for the more delicate but valuable kinds of trees, methods of after-care and tending. Since 1925 more intensive experiments have been laid down in order to find out whether it is possible to convert poor moorland soils into forest at this altitude in Scotland. These plantations have proved to be of immense value and encouragement to all workers engaged in the scientific investigations of peat, and in due course further results of fundamental value cannot fail to emerge.

The special methods of the fixation and planting of shifting sand dunes, so important in many places in the Empire and in different countries, can be seen and studied in detail at Culbin on the Moray Firth.

Education.—The Forestry Department of the University of Aberdeen provides a full course in Forestry training, leading up to the degree of

B.Sc. in Forestry. Special courses are also provided for apprentice foresters, agricultural graduands and those who intend to qualify for general plantation work.

Societies.—A branch of the Royal Scottish Forestry Society was instituted in Aberdeen in 1906, and has contributed to the advancement of forestry by holding regular meetings for the reading of papers by eminent foresters; discussions on forestry subjects and visits to forestry estates have marked the activities of the branch.

The Moray and Nairn Forestry Society, formed in 1923, is sustained and conducted by purely local enterprise and enthusiasm, and has done much to promote the development of scientific and practical forestry in the Elgin and Forres districts.

Farther north, there is the Inverness branch of the Royal Scottish Forestry Society. Among the many useful functions it has served is the promotion of practical competitions in wood-craft. This has been an outstanding feature.

Settlement Schemes.—The following facts will indicate what the Forestry Commissioners have already done and what they will accomplish in future in maintaining and increasing the forest area and forest industries, which are so intimately bound up with the development and prosperity of the North of Scotland.

The Forestry Commissioners have created 30 new Forest Workers' Holdings on the extensive forests of the Great Glen in Inverness-shire and a further 10 on adjacent estates. There are 182 persons resident on these settlements. The holders themselves are guaranteed employment for six months in the year on the forest areas. In practice, the amount of work available has permitted their employment for periods considerably in excess of six months. So far as can be ascertained, the number of people regularly employed on these estates by the Commission is five or six times the number employed when the lands were in private ownership. The stock owned by the 40 holders is valued at £977.

On the estates of The Bin and Clashindarroch, in the Huntly district, 20 holdings have been formed, housing 87 persons, including 22 employees. The holders' stock is valued at £552. A further 17 holdings have been made on the Culbin Forest and on Newton Farm in the Forres-Elgin district, where a large forest nursery is in course of development. Here the total residents number 76, of whom 22 are employed by the Commission. Other less important settlements have been created in the Aberdeen University area, as at the Forest of Deer, Drumtochty, Scootmore, Teindland and other places.

The Timber Industry of Aberdeen.—The timber trade in Aberdeen is one of the most important trades in the city.

Aberdeen, being situated on the east coast, and being very accessible for shipping from the Continent, is the port for the importation of timber for the North of Scotland. The average annual importation into Aberdeen of foreign timber by sea (i.e. through the Customs) in 1932 and 1933 was about 3,000,000 cubic ft. of timber. The actual importation in 1933 was 2,358,654 cubic ft. (up to the end of November 1933), and the sources were: Norway, 122,050 cubic ft.; Finland, 541,650 cubic ft.;

Sweden, 292,850 cubic ft.; Latvia, 91,100 cubic ft.; Russia, 1,188,150 cubic ft.; Germany, 89,828 cubic ft.; France, 3,550 cubic ft.; America, 24,250 cubic ft.; Canada, 2,976 cubic ft.; Burma, 250 cubic ft. This makes a total of 2,358,654 cubic ft.

The Customs' figures for sea-borne imports during 1933, however, do not necessarily indicate the actual consumption of timber during that period. There was a large carry forward of stocks from 1932, and a certain quantity of foreign timber also arrives by road and rail, and although no statistics are available, home-grown timber still bulks largely in the annual consumption. The quantity required for the building trades, principally during the year 1933, amounted to 78,000 loads or about 4,000,000 cubic ft.

The city is well supplied with sawmills. These mills are equipped with up-to-date wood-working machinery, and are kept fully employed in the rehandling, resawing and dressing of this timber for distribution mainly to the building trades in the city and over the whole of the North of Scotland, including Orkney and Shetland.

For the box-making industry, Aberdeen imported during 1933, 5,000 fathoms or about 1,100,000 cubic ft. of round timber. The greater part of this timber is used in the manufacture of all kinds of fish boxes, packing cases, for home and export trade; herring barrels, etc., in the many excellently equipped factories. These manufactures are well known over the whole of Britain. Forty to fifty years ago, 100,000 fish boxes were used annually; by 1924 the number had increased to 4,000,000. At the present day 12 cubic ft. of wood is required per ton of fish boxed.

It is not possible to say how much home timber is used for this purpose, but one firm alone in the box-making trade requires 300,000 cubic ft. of round and sawn home timber per annum. It is confidently believed that better organisation of marketing facilities would lead to a larger consumption of home timber.

It is interesting to examine the sources of the sea-borne imports which make up the Customs' figures. In the total given above the bulk of the importation was red wood and white wood (pine and spruce), and it will be seen that the bulk of it came from Russia; birch and maple came from Canada; hardwoods from Germany; poles from Sweden; laths from Norway; chestnut from France; firewood from Sweden; flooring and planed goods from Norway and Sweden; red wood mainly from Russia and Finland; teak from Burma; staves from Norway and Sweden; deals, battens and boards from America, but the bulk from Europe. In the same period in 1933 most other ports in Great Britain exceeded the figures for 1932 in timber importations except Aberdeen. This was due largely to the box and barrel trade being depressed. In the autumn of 1933 Aberdeen box-makers, through a representative of the box-making firms who visited Newfoundland, were able to fix up contracts on what were regarded as favourable terms, for about 5,000 fathoms of timber. This action is of importance for several sound reasons, not the least among which is that Canada, invoking the Ottawa agreement, has been pressing this country to put an embargo on Russian timber. The

Aberdeen box-makers have thus acted on their own accord, without waiting for Government pressure, and it is to be generally hoped that the new source of supply will be found to meet their needs.

In connection with the home timber industry, Aberdeen is well to the fore, being situated within economic distance of the finest timber-growing districts in Britain, viz. Deeside, Donside and Speyside. In these districts about thirty sawmills are continually employed producing boarding for box-making and staves and heading for barrel-making. They also produce large quantities of timber for the mining industry, railway sleepers and fencing for the railway companies, and for general work. The total output from these mills during the past twelve months (in 1933) amounted to approximately 2,350,000 cubic ft.

VII.

THE CLIMATE OF ABERDEENSHIRE

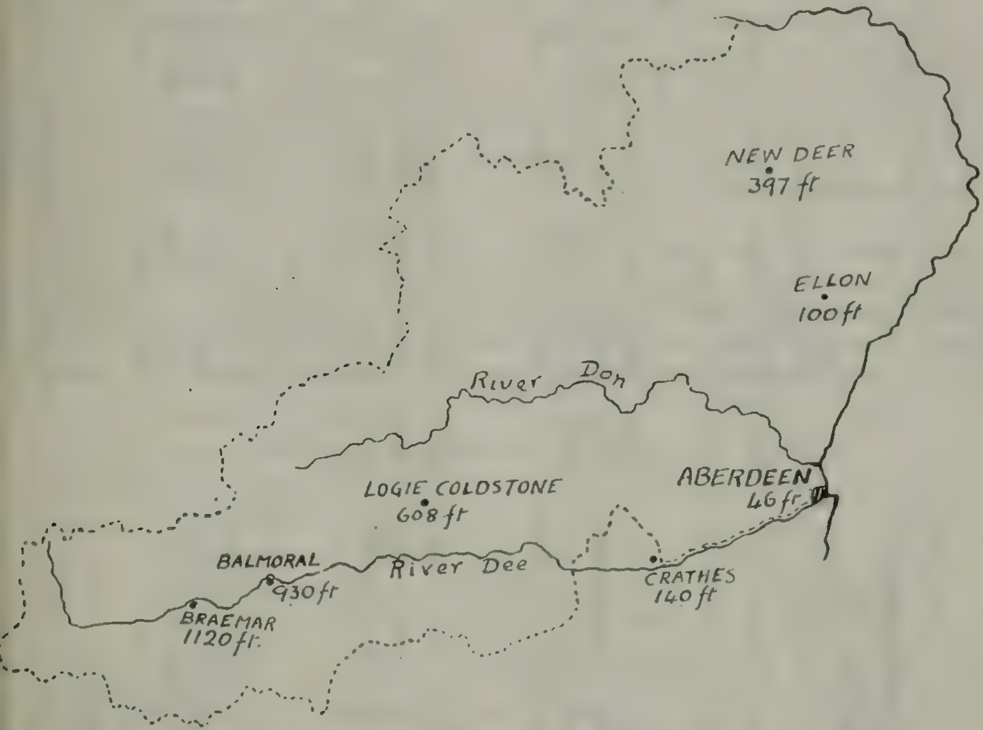
BY

G. AUBOURNE CLARKE, F.R.Met.Soc.

General Conditions.—From the climatic point of view the county of Aberdeenshire is somewhat peculiarly placed. Its western extremity lies in the central highlands of Scotland where large areas of the ground rise above the 2,000-ft. level, while the relatively low land of its north-eastern extremity is washed both on the north and on the east by the waters of the North Sea. Considerable differences in climate throughout the county are therefore naturally to be expected.

Meteorological data over considerable periods are available for the valley of the river Dee, from Aberdeen Observatory on the sea coast at the mouth of the river and from Balmoral and Braemar on the high ground at its upper reaches ; also from Logie Coldstone which occupies a somewhat sheltered position farther down the river than Balmoral. In addition there are statistics of rainfall and sunshine from Crathes, a station which, though actually lying in the neighbouring county of Kincardine, is situated on the north side of the river Dee about half way between Aberdeen and Logie Coldstone ; and also rainfall data from Ellon and New Deer in the north-eastern part of the county. These stations are shown in the accompanying sketch map.

The statistics given in this article have been supplied by permission of the Director of the Meterological Office.



ABERDEENSHIRE—Showing Meteorological Stations and their heights above M.S.L.

TEMPERATURE.—Table I shows the temperatures recorded at Aberdeen, Logie Coldstone, and Braemar during the period 1901–30. For each of these stations there are given the mean maximum and minimum temperatures and also the mid-temperatures for each month and for the year. Finally there is shown the mean daily range for each month and for the year.

The table shows clearly the differences in the climate of the sea-coast and that of the higher regions inland. For example, at Aberdeen the June maximum is 58·7° F., while at Logie Coldstone it is 61·7° F., and at Braemar, despite a height of 1,120 ft., it reaches 60·6° F. The corresponding minimum temperatures are 47·0°, 44·1° and 42·2° F., Aberdeen having thus much warmer nights. The daily ranges for this month are 11·7° F. at Aberdeen, 17·6° F. at Logie Coldstone and 18·4° F. at Braemar.

The table also shows that at the inland stations the winter temperature is much lower than at Aberdeen, while the daily range is nevertheless larger. The annual range of monthly temperature at Aberdeen is 17·5° F. and at the other two stations it is 20·1° F.

It is interesting in this respect to note that if the averages over the period 1881–1915 are employed instead of those over 1901–30, the mean

TABLE I.—TEMPERATURE, ° F.

PERIOD 1901–30.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
ABERDEEN													
Mean Max. . .	42·8	43·1	45·0	48·6	53·6	58·7	61·9	61·4	58·2	52·5	46·2	43·3	51·3
Mid. Temperature .	38·8	38·9	40·3	43·1	48·0	52·9	56·3	55·9	52·5	47·6	41·9	39·4	46·3
Mean Min. . .	34·8	34·8	35·6	37·7	42·4	47·0	50·7	50·3	46·9	42·7	37·6	35·5	41·3
Mean Daily Range .	8·0	8·3	9·4	10·9	11·2	11·7	11·2	11·1	11·3	9·8	8·6	7·8	10·0
LOGIE COLDSTONE													
Mean Max. . .	41·6	41·9	44·7	49·8	56·0	61·7	64·4	62·6	59·0	52·2	44·7	41·4	51·7
Mid. Temperature .	36·3	36·3	38·2	41·9	47·6	52·9	56·3	54·9	51·1	45·3	38·9	36·2	44·7
Mean. Min. . .	31·1	30·8	31·7	33·9	39·2	44·1	48·1	47·2	43·1	38·4	33·2	31·0	37·7
Mean Daily Range .	10·5	11·1	13·0	15·9	16·8	17·6	16·3	15·4	15·9	13·8	11·5	10·4	14·0
BRAEMAR													
Mean Max. . .	40·1	40·5	43·0	48·0	54·9	60·6	63·5	61·2	57·6	51·0	43·7	40·6	50·4
Mid Temperature .	34·8	34·6	36·4	40·3	46·2	51·4	54·7	53·3	49·5	43·9	37·5	35·1	43·1
Mean Min. . .	29·5	28·7	29·8	32·5	37·5	42·2	46·0	45·3	41·3	36·9	31·4	29·6	35·9
Mean Daily Range .	10·6	11·8	13·2	15·5	17·4	18·4	17·5	15·9	16·3	14·1	12·3	11·0	14·5

July value for Aberdeen is 56·7° F. and that for January 37·8° F. instead of 56·3° F. and 38·8° F. respectively; a fact which bears out the general impression that our winters have been milder of late years. Corroboration is forthcoming from Braemar, whose earlier values were 54·8° F. and 34·3° F. as compared with 54·7° F. and 34·6° F. in the later period.

Some extreme temperature values might be of interest. At Aberdeen the highest temperature so far recorded was 86° F. on July 16, 1876, and the lowest was 4° F. on January 18, 1881. At Braemar a temperature of − 12° F. was experienced on February 8, 1895, during a prolonged spell of frost.

Rainfall.—The incidence of rainfall throughout the county, as tabulated in Table II, shows some points of interest. As is usual in our islands, the rainfall of the first half of the year is definitely less than that of the second half; Aberdeen, for example, receiving 12½ ins. from January to June as compared with 17 ins. from July to December.

Table II.—Rainfall. Period 1881–1915

	Aberdeen	Crathes	Logie Coldstone	Balmoral	Braemar	Ellon	New Deer
Height in ft. above M.S.L.	46	145	608	930	1,120	100	397
	In.	In.	In.	In.	In.	In.	In.
January .	2·18	2·64	2·21	2·76	3·19	2·13	2·33
February .	2·05	2·54	2·08	2·60	2·85	2·10	2·13
March .	2·41	2·80	2·60	2·86	2·98	2·42	2·59
April . .	1·87	2·09	2·01	2·15	2·37	1·89	1·99
May . .	2·33	2·52	2·49	2·32	2·38	2·28	2·18
June . .	1·71	1·78	1·95	1·70	1·96	1·75	1·99
July . .	2·81	2·93	2·96	2·55	2·57	2·82	3·06
August .	2·74	3·03	3·17	3·03	3·41	2·75	2·96
September .	2·22	2·36	2·33	2·40	2·51	2·34	2·52
October .	3·00	3·50	3·24	3·60	3·76	3·20	3·80
November .	2·95	3·34	3·07	3·69	3·84	2·93	3·37
December .	3·22	3·60	2·81	3·38	3·56	3·17	3·42
Year . .	29·49	33·13	30·92	33·04	35·38	29·78	32·34

In the table the variation of the rainfall from month to month throughout the year shows the same broad features at all stations; April and June being dry months in the first half of the year, and September a dry month in the second half. One minor point of interest is that at Aberdeen,

Crathes and Ellon, December is somewhat wetter than November, while at the three westerly stations November is the wetter of the two, and at New Deer both months have practically the same precipitation.

The annual rainfall is less along the coast than it is inland, ranging from 29·5 ins. at Aberdeen to 35·4 ins. at Braemar. Logie Coldstone, probably on account of its sheltered position, receives rather less rain than might be expected from its height above sea-level.

Aberdeen lies just within the 30-in. isohyet which runs down the east coast of Scotland, but there have been occasions on which that value has been departed from considerably. In 1872 Aberdeen experienced its wettest year, when 44 ins. were recorded, while the driest year was 1921 with only 17 ins. The wettest month so far recorded was December 1876 with nearly 9 ins., and the driest was March 1929 with only one-fifth of an inch. The heaviest fall in 24 hrs. was 2·8 ins. on November 7, 1873.

SUNSHINE.—Sunshine records are available for Aberdeen Observatory and are set forth in Table III.

TABLE III.—SUNSHINE AT ABERDEEN. PERIOD 1881–1915

Month.	Hours per Day	Per cent. of Possible	Month	Hours per Day	Per cent. of Possible
January . .	1·55	21	August . .	4·84	32
February . .	2·59	28	September .	4·13	32
March . .	3·77	32	October . .	3·06	30
April . . .	5·27	37	November .	1·83	23
May . . .	6·03	37	December . .	1·16	17
June . . .	6·13	35			
July . .	5·13	30	Year . .	3·80	31

Aberdeen lies within the sunny strip running along the east coast of Scotland; April and May, each with 37 per cent. of the possible sunshine, are the months with clearest skies. In April 1906 the unusually high value of 56 per cent. of possible sunshine was recorded, and in September of the same year the figure was 53 per cent. Contrasted with this brightness, December 1903 had only 3½ per cent. of the possible.

Records taken at Crathes over the same period show a yearly average of 3·65 hrs. of sunshine per day, or 30 per cent. of the possible, thus closely approaching the figures for Aberdeen.

At Braemar a sunshine recorder has been in use since 1929, but its exposure was at first unsatisfactory and a considerable amount of sunshine was cut off by buildings and trees in the neighbourhood, so that a direct comparison with Aberdeen values is not possible. But over the period

1929 to 1933 Braemar had an average duration of 2·90 hrs. per day compared with 3·67 at Aberdeen.

SNOWFALL.—Table IV gives the average number of days in each month upon which snow falls and also the number of days on which the ground remains covered with snow.

TABLE IV.—NUMBER OF DAYS OF SNOW AND SNOW LYING

Month.	Aberdeen		Balmoral		Braemar	
	Snow 1881–1933.	Snow Lying 1912–33	Snow 1906–33	Snow Lying 1912–33	Snow 1884–1905 1912–33	Snow Lying 1912–33
January	7·1	2·6	7·6	13·9	8·7	17·6
February	6·8	2·3	7·1	12·1	7·5	12·5
March	7·6	2·6	8·0	11·0	8·4	12·3
April	3·5	0·4	5·3	3·7	6·0	4·4
May	0·8	0	1·3	0·4	2·0	0·6
June	0	0	0·3	0	0	0
July	0	0	0·1	0	0	0
August	0	0	0·1	0	0	0
September	0·1	0	0·2	0	0·2	0·1
October	1·4	0·3	1·8	1·2	2·3	2·1
November	3·0	1·3	4·2	6·0	4·7	6·2
December	5·3	2·8	6·5	11·5	7·3	12·7
Year	35·6	12·3	42·4	59·9	47·1	68·5

There is a progressive increase in the number of days of snowfall from Aberdeen westwards to Braemar, but a still more significant increase in the number of days of snow lying, Braemar having more than five times as many as Aberdeen—due of course to the much lower winter temperature at Braemar.

MISCELLANEOUS PHENOMENA.—Some farther interesting data are given in Table V.

The relative humidity of the atmosphere at Aberdeen is shown in the first column ; its most interesting feature is the small difference between the summer and winter values, indicating relatively dry air even in winter—resulting from the situation of Aberdeen on the sea-coast.

The statistics of thunder at the three stations show that Braemar is less liable to thunderstorms than are Balmoral and Aberdeen.

At Aberdeen hail falls on the average on sixteen days in the year, one-half of these days occurs in the three months March, April and May.

At Balmoral there is night frost on the ground on two-fifths of the days of the year ; it may occur in every month—even in July.

Winds at Aberdeen blow chiefly from directions in the south-west and north-west quadrants, and are least frequent in the north-east quadrant. Gales are relatively infrequent and blow chiefly from the west and south-west ; those from east and south-east tend to endure for a longer time when they do occur. A sea-breeze effect is often felt during fine summer weather.

TABLE V.—MISCELLANEOUS PHENOMENA

Month	Aberdeen			Balmoral		Braemar
	Relative Humidity Per cent 1886–1910	No. of Days of Thunder 1881–1915	No. of Days of Hail 1881–1915	No. of Days of Thunder 1914–1933	No. of Days of Ground Frost	No. of Days of Thunder 1914–1933
January .	80·3	0	1·9	0	23·3	0
February .	79·2	0	1·1	0·1	20·7	0
March .	78·8	0	3·2	0	21·5	0
April . .	78·3	0·2	2·8	0·3	17·3	0·2
May . .	78·8	0·7	2·0	1·0	9·0	0·9
June . .	78·2	1·3	0·4	0·8	2·8	0·7
July . .	78·3	2·0	0·1	1·9	1·6	1·3
August .	79·2	1·5	0·1	1·6	0·9	1·0
September .	80·5	0·4	0·2	0·2	5·2	0
October .	82·3	0·1	1·2	0·2	10·1	0
November .	82·1	0·1	1·2	0·2	17·6	0
December .	82·1	0·1	1·7	0·3	21·5	0·3
Year .	79·8	6·4	15·9	6·6	151·5	4·4

Fog is much more common during the summer half of the year than during the winter, and occurs chiefly in the early summer with south-east winds. On the average there are seventeen days with fog in each year at Aberdeen.

In addition to the above selected stations there are about 30 others for which rainfall data are available.

VIII.

EDUCATION

BY

JAMES DAWSON, D.S.O., M.A.,

DIRECTOR OF EDUCATION, ABERDEEN.

THE first reference to schools in Aberdeen was made in the Statutes of the Church of date 1256. A school in Inverness was referred to in a Deed of 1316, and schools in connection with Elgin Cathedral and St. Magnus Cathedral, Lerwick, were mentioned early in history. The Town Councils of these and other burghs seem to have given early support to church schools established for the purpose of giving instruction in Latin and music, and gradually to have assumed their control. The Aberdeen Grammar School is, for instance, a direct successor of the early church school, and we find that the 'Sang' School of the city, known to exist prior to 1370, was for centuries carried on by the Town Council. The burghs in the course of time provided schools for the teaching of subjects other than Latin and music, and they also sanctioned the opening of private schools, but only if the subjects of instruction proposed were not those for the teaching of which they themselves had already made provision. The establishment of schools for elementary education in the larger centres of population grew with the extension of the church or through the benevolence of private citizens and trusts.

In John Knox's *First Book of Discipline* (1560–61) there was outlined a scheme of education which aimed at establishing all grades of seminaries from parish schools to universities, and at making education compulsory for all and free to the poor. For various reasons the plan was only very imperfectly realised. An Order in Council of 1616 ordained the erection of a school in every parish, and the movement was supported by Acts of Parliament passed in 1633, 1646, 1669 and 1803. The development of parish schools in the counties of Aberdeen, Banff and Moray was greatly assisted by the operation of the Dick Bequest, which since 1833 has ensured the settlement of a man of sound education—practically always a university graduate—in every parish school. The Trust still continues its grants. Some very good work was done in the parish schools, and many 'a lad o' pairts' went straight from his parish school to the university, where, supported by a bursary gained in competition, he found himself on the way to a useful career.

The object of the Education (Scotland) Act, 1872, was to ensure that the means of procuring efficient education for their children might be furnished and made available for the whole people of Scotland. This Act and the Act of 1918 are really only the modern expression of the ideals contained in the *First Book of Discipline*.

Education in Scotland was administered by Parish School Boards from 1872 till 1918, when the county (four scheduled burghs excepted) became the administrative unit. The education authorities elected under the 1918 Act were *ad hoc* bodies, but under the Local Government (Scotland) Act of 1929 the functions of the education authorities were, in 1930, transferred to the County and City Councils.

The north-eastern and northern districts of Scotland are particularly fortunate in the number and value of their benefactions, and the facilities thereby provided for attendance at secondary schools and universities are probably unequalled in any other district. Reference will be made later to university bursaries, but it may be here mentioned that there is available from trust funds alone over £4,500 per annum for bursaries to pupils attending secondary schools in the city of Aberdeen.

The two foundations of the 'University and King's College of Aberdeen' and 'Marischal College and University of Aberdeen' were on September 15, 1860, united under the title of the 'University of Aberdeen.' What was the origin of the colleges thus amalgamated? In the case of the first mentioned—King's College—we have to go back to the year 1494, when King James IV, at the request of William Elphinstone, Bishop of Aberdeen, obtained a Papal Bull sanctioning the establishment of a college in Old Aberdeen for giving instruction in theology, in civil and canon law, in medicine, in the liberal arts, and also in any other lawful faculty. It may be remarked that this is the first mentioned provision in Great Britain for the teaching of medical science. The second of the two colleges mentioned—Marischal College—was founded in New Aberdeen in 1593 by Earl Marischal, who was at the time Lord-Lieutenant of the North. The college was intended to be a place where the youth of the Royal Burgh might obtain 'an honourable, liberal, and Christian education and training.' His intention having been previously communicated to the magistrates of the city, they purchased the buildings and land of the Franciscan friars on the east side of Broadgate, and presented the property to the Earl for the site of his college buildings—an early indication of the close association of Town and Gown. These two colleges, both of them exercising university rights and privileges in buildings only about a mile apart, co-existed for over 260 years as independent and rival institutions. It would appear that students from the city and its immediate neighbourhood attended, as a rule, Marischal College, and that King's College drew its students from the northern districts. As might be expected, there were constant conflicts between the students of the two colleges, as well as jealousies among the masters.

At the fusion in 1860, numerous rearrangements and adjustments were necessary, and these affected not only the staff but also the distribution of the classes between the two buildings. The present arrangement is, generally speaking, for most of the classes in the Faculty of Arts and the classes in the Faculty of Divinity to be conducted in the King's College buildings, while the classes in the Faculties of Medicine, Law and Science meet in Marischal College. In session 1933–34 there were 1,270 students in attendance, of whom 362 were women. They were

distributed among the various faculties and departments as follows: Arts, 509; Science, 198; Medicine, 455; Law, 46; Divinity, 37; Commerce, 23; Education, 2. It is on account of the magnificent endowments connected with the University that no one, however humble or however poor, need go without the advantages of higher education. Bursaries are available in all the faculties, but they are especially valuable and numerous in the Faculty of Arts, in which there are 265 bursaries of an aggregate annual value of over £7,000. The bursaries are mostly competitive, largely unrestricted, and usually open to women as well as to men.

The chapel and the Crown Tower alone remain of the original buildings at King's College. Near the west door of the chapel is an inscription giving 2nd April 1500 as the date when the masons began to build under the auspices of King James IV, here described as 'Invictissimus'! In the chapel is an elaborate and richly carved screen which has few equals in Great Britain. Other interesting features are the tomb of the founder in the main chapel and his memorial with recumbent figure in the ante-chapel. Of the original buildings at Marischal College practically nothing remains except the stone with the famous inscription, 'Thay haif said; quhat say thay; lat thame say,' which is still preserved in the vestibule under the Mitchell Tower. The front extension of Marischal College, which has been described as a 'poem in stone,' was inaugurated in 1906 by King Edward VII.

The University has for generations carried on a great work for the educational enlightenment and progress of the North of Scotland, and it has contributed to the world many men who have rendered distinguished service to civilisation and science, and who have brought fame to themselves and honour to their Alma Mater.

Aberdeen has always stood for education as a factor of the highest importance in the lives of the citizens, and it has made liberal provision for the achievement of its educational ideals. The schools under the administration of the Town Council may be classified as follows:

	Number.	Average enrolment (approximate).
Secondary . . .	3	2,500
Primary	26	20,000
Intermediate . . .	7	5,000
Special	2	250

It has already been stated that there is on record a reference to the schools of Aberdeen in 1256. The history of the Grammar School, which had its origin in the church schools referred to, is wonderfully complete, and it is interesting to note that there is an unbroken record of the succession of Rectors from 1479. The school was for ages regarded as exclusively a day school for classical education in preparation for the University. The instruction was given wholly in Latin, the use of English by teachers and pupils being forbidden. The original Grammar School stood on the ground in Schoolhill now occupied by Gray's School of Art. We learn that in 1527 the masters of the Grammar School

complained that the school was about to fall down, and that the Master of Kirk Work was ordered to 'mend' it. In 1623 a new school was built, but the buildings familiar to the last generation were erected in 1757. They were vacated in 1862, just six hundred years after the school's first definite mention in history. The present buildings in Skene Street were occupied in 1863, but substantial additions have been required from time to time to meet the demands for admission. The enrolment last session was 793, 438 being in the secondary department. There is in the main building a fine assembly hall, recently overhauled and re-decorated. A sports field of nearly 12 acres provides excellent facilities for organised games, which are a compulsory part of the school curriculum. Among the distinguished sons of the school may be mentioned Lord Byron, who entered in January 1795, and, as he says in a letter, 'threaded all the classes to the fourth.' A statue of Lord Byron stands in front of the school.

An English School situated in Little Belmont Street was, in 1874, transferred by the Town Council to the first School Board. It had then in attendance only 60 pupils of both sexes, but after reorganisation it was successful as a Girls' Academy and became known as the High School for Girls. In 1881 the school was recognised as a Higher Class public school, and it was removed in 1893 to the present buildings in Albyn Place. These were extended in 1904 and additional accommodation was obtained in 1919. A new play field of nearly 12 acres with a handsome pavilion is now ready for use by the school. The school provides an efficient training in academic subjects to the Leaving Certificate stage, but it also affords full opportunities for the study of non-academic subjects, permitting specialisation in music, art and domestic science. The pupils in attendance in session 1933–34 numbered 895, of whom 418 were in the secondary department.

The Central Secondary School was opened in May 1894 as an 'ex-standard' school, but it is now conducted under the Secondary School Regulations, and provides five-year courses for both boys and girls, leading to presentation for the leaving certificate of the Scottish Education Department. The enrolment in session 1933–34 was 811. There is no primary department attached to the school, admission to which is granted only after a satisfactory appearance in an entrance examination. No fees are charged at any stage, and free books are supplied till pupils reach the age of fourteen years. The Central Secondary School is also the recognised Intermediate Centre for pupils who wish to follow a general or literary course, the other intermediate courses being provided in various schools throughout the city. Since 1929 there has been carried on in the school a one-year Commercial Course for the preparation for office work of girls who have obtained the Day School Certificate (Higher) in this school or in any intermediate school. The buildings in Little Belmont Street, vacated by the pupils of the High School for Girls in 1893, provided sufficient accommodation at the opening, but these were extended in 1896, and the new section in Schoolhill was opened in 1905.

In 1921 the Education Authority, having previously revised the schemes

of work for pupils up to twelve years of age, devised courses of post-primary instruction which differed in kind rather than degree from the early stages of a secondary course, the new courses making their special appeal to pupils of different tastes and different, though not inferior, capabilities. The Education Authority further realised that full benefit of the instruction to be provided in these new courses, largely practical and extending over three years, could best be got from centralisation. The city was accordingly divided into five areas, and a school in each was selected as an intermediate centre. To those selected schools pupils from the primary schools of the district are transferred at about the age of twelve on passing a control examination held twice yearly. The schools may thus be described as ‘ Central Selective ’ in terms of the Hadow Report. Reorganisation was carried through in three stages during the years 1922, 1923 and 1924. A redistribution of the city population made the provision of additional schools of this type necessary in outlying districts, and two others have been opened recently, one in 1927 and the other in 1932. All these intermediate schools, which provide for both boys and girls, are staffed by specialists—men for boys and women for girls. Books and stationery are supplied free, and sports facilities provided. Every endeavour is made to make this important stage of school life as effective, attractive and profitable as possible.

The city is fortunate in its facilities for organised games. All the senior and intermediate pupils, numbering over 12,000, attend a play field for games once a week. Three special grounds, totalling 24 acres and supplemented by the public parks and Town Links, provide the necessary accommodation. Arrangements are also made in season for the playing outwith school hours of football, hockey, cricket and netball, and for the practice of field athletics. A pond attached to the Middle School provides facilities for instruction in swimming.

Art appreciation and picture study is fostered in city schools by the circulation of twenty-seven sets of reproductions of famous pictures, each set remaining in primary schools for six months at a time, and in intermediate and secondary schools for twelve months. An essay scheme, supported by the award of prizes and certificates, is carried on in connection with the collection.

The Authority also carry out their statutory duties with regard to the medical inspection and treatment of school children, and provide central clinics for teeth, eye, and ear, nose and throat work. A bath-house containing twenty-four spray baths with the necessary dressing accommodation was erected in 1927, and arrangements are made for the attendance thereat of senior pupils from schools in its district. The total attendances of pupils during school hours average 28,000 per annum.

A ‘ Parents’ Day ’ is held in each primary and intermediate school at least once every two years, an occasion when the schools are thrown open for inspection and the opportunity offered to all interested to acquire at first hand some knowledge of school conditions and working arrangements. Further association with the home arises out of the evening Play Centres scheme which was instituted in 1918. There are now 10 schools utilised

for this purpose, providing accommodation for 2,200 pupils nightly three times per week.

While provision is made for the education of the normal child, the needs of the child who is unable to benefit by attendance at an ordinary school are not overlooked. The Education Authority make special provision for the education and training of mentally and physically defective children, deaf mutes, and the blind.

Robert Gordon's College, a secondary school for boys, is administered by Governors under powers granted them in 1881, and is a development from Robert Gordon's Hospital, a benevolent educational institution opened in 1750. By a Deed executed in 1729, Robert Gordon, formerly a merchant in Danzig, mortified his whole substance and effects for the building of an hospital, and for the maintenance, aliment, entertainment and education of young boys whose parents were poor and indigent. The original hospital buildings form the central block of the present school. The Provisional Order of 1881 provided for the conversion of the hospital buildings into a College or Day School, the foundation in future to be designated 'Robert Gordon's College in Aberdeen.' The college quickly gained the confidence of town and county, and by August 1884 it had a full complement of 600 boys. With modifications to meet the changing conditions, the college, which is very well endowed with foundations and bursaries, is still carried on under the original powers. In February 1934 the enrolment was 999, of whom 289 were in the primary department and 710 in the secondary department. A play field of 12 acres provides adequate recreational facilities, and the amenities of the college were enhanced in 1930 by the opening of a handsome assembly hall.

By the Provisional Order of 1881 the Governors of Robert Gordon's College were empowered to carry on day or evening classes for boys, girls and adult persons. Evening classes were begun in the college in 1882, and have been carried on continuously ever since, the instruction being since 1902 of a special or advanced nature. The Provisional Order of 1881 also permitted the Governors, by agreement with the directors of the Mechanics Institute, to amalgamate the Institute (founded in 1824) with the college, and such an amalgamation took place in 1884, when the whole educational work, including what was known as the Aberdeen School of Art, was transferred to the college. A further Provisional Order obtained in 1909 contained the following provision: 'The Governors shall establish in the city a College of Technical Instruction for the city and for the North of Scotland, to be called Robert Gordon's Technical College.' Thus came to be created the local technical college, now recognised by the Scottish Education Department as a Central Institution. The schools at present constituting the technical college are: (1) Engineering, (2) Chemistry and Pharmacy, (3) Art and Crafts, (4) Domestic Science, (5) Navigation. In the case of the School of Engineering there is co-operation with the university authorities in the provision of classes for the B.Sc. in Engineering at the university and for the Diploma of the Technical College. The number of students who attended day classes in the

college last session was 855 ; at the evening classes the enrolment was 942. Plans for the erection of permanent buildings in the grounds of Robert Gordon's College were approved in 1914, but operations were delayed by the War and other circumstances until the beginning of 1925, when a commencement was made with the erection of the main building and the extension of Gray's School of Art. These were completed in 1929, and the various schools, well housed and staffed, and supplied with up-to-date equipment, are in every way fitted to fulfil their purpose.

Reference to the facilities provided for agricultural education will be found elsewhere in this publication, but some other special establishments require mention here.

A Church of Scotland Training College for Teachers established in 1873, and a similar Free Church Institution dating from 1875, were amalgamated in 1907 and placed under the control of a Provincial Committee consisting of representatives of education authorities, university, churches and teachers. New buildings planned in 1912 were not, owing to the intervention of the War, fully occupied till 1922. Hostels to accommodate 115 women students were opened in 1927. The training of all classes of teachers, except specialists for Physical Training and Music, is undertaken, 54 male students and 241 female students being in attendance during session 1933–34. It may be recalled that Sir John Adams, the noted educationalist, was Principal of the Free Church College from 1890 till 1898.

The Divinity Hall, Aberdeen, was opened in 1850 for the training of students for service in the Free Church of Scotland. Since the Church Union in 1929, working arrangements with the Faculty of Divinity at the University have been in operation, and negotiations for amalgamation are now proceeding.

St. Mary's College, Blairs, near Aberdeen, is a national Catholic secondary school devoted solely to the education of students in training for the Catholic priesthood in Scotland. After qualification, the students proceed to colleges for higher ecclesiastical studies in Glasgow, or on the Continent. There are at present over 100 students in residence at the college.

The Sutherland Technical School, Golspie, erected in 1903, was looked on at the time as an interesting educational experiment. It is a residential school providing accommodation for 50 boys drawn from the families of fishermen and crofters in outlying districts of the county and giving them a three years' course of education and training for trades and outdoor occupations. It was managed by Governors till 1922, when it was taken over by the County Education Authority.

Broadly speaking, the scheme of instruction in continuation classes in Aberdeen City may be divided into four sections : (1) Classes for the completion of general elementary education ; (2) Classes and courses for specialised instruction for various occupations—industrial, commercial, professional ; (3) Domestic classes and courses ; (4) Auxiliary classes, such as vocal music and physical training. With the exception of the industrial courses, the Education Authority are responsible for the whole of the training up to the final stages. In the industrial courses the

work is carried on by the Authority till the end of the second year, on the successful completion of which the pupils join the third-year classes carried on in the Technical College. There has been a steady extension in the number and diversity of the classes offered in the schools, and every call for cultural education as well as every desire for technical instruction has been met, so far as the demand for these has justified action being taken. Classes in economics, public finance, public administration, organisation of industry, motor maintenance, wireless theory, general salesmanship, window-dressing and gardening, and courses for butchers, paper-makers, motor engineers, confectioners and bakers are among the many additions to the evening classes scheme within recent years. On the completion in 1924 of the system of intermediate schools for post-primary pupils, it was considered that these were the appropriate centres in which to conduct the evening classes for the respective districts. Such an arrangement enabled the instruction provided in the evening schools to be carried out as far as possible under the same conditions in respect of environment, syllabus and teachers as obtained in the day school, thus admitting of the very closest continuity between the two sections of the pupils' school life. In addition to these arrangements special classes of a varied nature are conducted in other city schools. A very close connection has been developed between the evening classes and industry, as evidenced by the setting up of advisory committees for various trades and occupations. These committees consist of equal numbers of employers and operatives, and are intended to advise on curricula, to visit classes, to make recommendations for the appointment of teachers of practical subjects, and generally to represent the various industries in the management of the classes. At present there are sixteen such committees acting in the direction indicated. An official was appointed by the School Board in 1912 to take charge of this department of their activities. The present organiser, who provides the necessary link between the Education Authority and the Ministry of Labour with regard to the placing of juveniles in suitable employment, is also in charge of an Appointments Bureau which deals with secondary school pupils and employment. The enrolment at classes carried on by the Education Authority in session 1933–34 was 7,566; at the classes held in the Technical College there were in attendance 942 students.

In this short sketch it has not been found possible to present more than an outline of some local educational activities, with a few historical notes. It is to be hoped that the article will prove of sufficient interest to some readers to encourage them to make inquiry for fuller information.

IX.

ARCHITECTURE IN ABERDEEN: A SURVEY

BY
WILLIAM KELLY, A.R.S.A., LL.D.

MATERIALS.—Medieval buildings in Aberdeen and the adjacent district are few and of no outstanding importance, but they are not without interest. The local granite, including in the term other similar rocks and surface boulders, has at all periods been used for rubble-walling; but, except for a short period in the fifteenth century, every *cementarius* in Aberdeen was a master-mason of freestone, shaping and cutting freestone only in the exercise of his craft. Sandstone, practically the only kind of freestone used in the locality, was quarried at a few spots in the county, principally near Kildrummy; but the main supplies were brought to Aberdeen by sea, considerable quantities coming from Covesea in Morayshire.

After the short period above referred to, when granite took the place of freestone, it was not until the great era of castle-building in the sixteenth and seventeenth centuries that the local master-masons again used granite as a material for dressed work, shaping of it a group of castles, the most characteristic of all Aberdeenshire buildings.

The quarrying of granite on a large scale and its adoption for the purposes of mason-craft in Aberdeen—well-nigh to the complete exclusion of other materials—are comparatively recent developments which began in the eighteenth and came to maturity only in the nineteenth century.

Aberdeen is notable not only for its granite, but also—in Scotland at least—for its late-Gothic ecclesiastical woodwork, the remnant partly of importations from Flanders and partly of works by local carpenters, done in the first quarter of the sixteenth century.

Other unusual items of architectural interest are the sculptured stone Sacrament-houses, which are peculiar in Great Britain to the eastern part of Scotland, from St. Andrews to Pluscarden in Moray. Those at Kinkell, Kintore and Auchindoir in Aberdeenshire, and at Deskford and Cullen in Banffshire, are excellent examples; they all belong to the latest phase of Gothic and the first half of the sixteenth century.

Aberdeen possesses a number of interesting examples of the architectural and decorative use of lead, dating from the seventeenth and eighteenth centuries. The flèche of King's College Chapel, the small spires of the Tolbooth and Gordon's College, and the unique cast-lead traceried eaves-apron on the north transept of St. Nicholas' Church may be noted.

Norman Work.—The two great medieval churches—St. Machar's (the cathedral of the ancient diocese of Aberdeen) and St. Nicholas' (the Burgh Church)—were originally complete Norman edifices. At St. Machar's scarcely a worked stone of that period remains—none *in situ*. At St. Nicholas', some early Norman building may be seen in the transepts ; and at the crossing, Transitional work of fine character has escaped the changes and chances of seven centuries ; the noteworthy capital of the south-west pier seems to be of French derivation, possibly through Canterbury.

The only other Norman masonry in the county is at Monymusk Church, if a ruined fragment at Peterhead may be disregarded.

Early English Work.—The small ruined Chapel of Cowie, near Stonehaven (consecrated May 22, 1276), has a simple, well-proportioned gable with three lancet-lights. This is the only remaining example near Aberdeen of the pure and graceful style of the thirteenth century. Good Early English work occurs also at Kildrummy Castle and at Auchindoir Church. The ruined church of Kincardine o'Neil, which was one of the largest in the medieval diocese, shows some interesting advanced Early English work. Built early in the fourteenth century, the lateness of the development of style in the North is apparent.

Decorated Work.—After the middle of the fourteenth century (*c.* 1366) a new crossing, transepts and nave were planned for the Cathedral of Aberdeen, which at that time had a Norman nave and an Early English choir. The existing western piers at the crossing, their extension upwards —above the capitals—in *tas-de-charge*, the carved capitals which show natural knife-cut branches and wavy leafage and good animal and figure sculpture, along with some adjacent masonry, executed in the highest style of Decorated Gothic, are apparently all that was accomplished before this effort ended abruptly.

The Granite Interregnum.—It was not until after Bishop Henry de Lichtoun was translated from Moray to Aberdeen, in 1422, that the rebuilding of St. Machar's was resumed and the present nave and west front built of granite. The earliest granite ashlar in Aberdeen is that outside the north wall of the north transept. Lichtoun's work, which must be dated between 1423 and 1440, bears unmistakable marks of his direction : it was he who decreed that the west end of the cathedral should have two steeples, and that the west doorway should resemble that of Elgin, the Cathedral of Moray. Whether it was that freestone or that masons of freestone could not be procured at that juncture is not known. The mason whom Lichtoun employed was clearly no accomplished master, expert in the style of the day ; but it is equally clear that he could handle granite—probably he had done so hitherto as a castle-builder. For he raised two strongly buttressed fortress-towers, boldly machicolated (for use, if need be) with pathways behind battlemented parapets (since lowered) ; and for the rest, he could—and did—hark back to Norman forms and simplify mouldings to rough rounds and channels. But more : he contrived to build a great west window of seven very tall round-headed lights in a row, having sturdily built mullions between the lights—a window this, different from anything done before or since, and to be taken

as a fifteenth century Scottish equivalent in granite of an English Perpendicular end-window.

At some date before 1437 the Lady Elizabeth Gordon, 'heir of Huntly and Strathbogie,' built in connection with St. Nicholas' a new chapel, where she was buried in 1438. This chapel, 'our Lady's pity vault,' placed east of the old Norman choir on ground that sloped rapidly down, was planned as the first instalment of a new choir; so that when the extended new choir was built some forty or fifty years later, the chapel became an undercroft. Built entirely of granite, it consists of a nave-bay with north and south aisles, and an apsidal sanctuary-bay, all vaulted with ribbed cross-vaulting. The low bowed lines of the arches of St. Mary's—low of necessity, because of the choir above—are singularly effective; especially noticeable is the treatment of the diagonal rib-arches which spring from corbels set lower than the capitals of the piers from which the main arches rise.

From its style, the work must be attributed to a man having a better knowledge of normal Gothic forms than the mason of St. Machar's possessed.

With the completion of these two works the medieval use of granite masonry came to an end.

Late Gothic.—When, in the last quarter of the fifteenth century, the choir of St. Nicholas' was rebuilt, the work was done in sandstone by 'masons of the lodge'—latterly under Maistre Johne Gray. Apparently, to allow of the material for the choir being conveniently raised, the granite vaulting of St. Mary's, or part of it, was taken down; but when the work was reinstated, it was carried out in freestone. The corbels and the diagonal ribs of the nave-bay, the ridge ribs, the bosses and keystones are of sandstone. The corbels, bosses and keystones are carved, as are the wall-rib stops—one in the form of a small nude figure.

The choir of St. Nicholas' was pulled down in 1835, when the present (granite) East Church was built.

King's College Chapel, Old Aberdeen, begun on April 2, 1500, was by the end of 1506 so far advanced that the oak roof was ready for its lead covering. The most arresting feature of the chapel is the crown-steeple, one of two ancient examples left in Scotland; the other soars over St. Giles' and the old town of Edinburgh.

The eight-armed crown of St. Giles' is a little older than the four-armed crown of King's. St. Giles' tower is 29 ft. square, whereas King's measures 28 ft. 3 in. by 24 ft. 10 in., the larger dimension being on the west and east sides. The very great thickness of its south wall shows that the tower was begun as a square of nearly 25 ft.; afterwards the plan was made oblong, presumably in order that the crown steeple should appear from the west about as large as St. Giles'. Viewed from the north or the south, or nearly so, the steeple is much finer than it is as seen from the east or the west. The similarity of the details of the two crowns makes it almost certain that the master-mason of the chapel was from the Lothians, and that he knew and possibly had worked at St. Giles' steeple. But the original character of the Aberdeen steeple in large measure was lost when the upper part was rebuilt by a local mason after the crown had been

overthrown in a great storm of wind (February 7, 1633). George Thomson, the master-mason, used freestone ; but his lantern and upper ‘ imperial ’ crown are frankly provincial-Scottish, Caroline Renaissance, in place of the original Gothic spirelet over the junction of the four great ribs.

The general style of the College Chapel is Late-Scottish-Gothic, a style to be seen most perfectly in the Lothians. The east end shows the Scottish liking for apses of three or five sides. The nave was separated from the choir and sanctuary by a rood loft and screen, which divided the chapel into two nearly equal parts ; but about 1870 the loft was moved westwards, reducing the nave to an ante-chapel. The width of the chapel and of the nave of St. Machar's is the same (29 ft.) ; the chapel bays are 20 ft. long, as compared with 17 ft. bays at St. Machar's. This large dimension gave scope for the series of great windows on the north side. It is remarkable that the style of these windows—at least of the tracery—should approximate to the ‘ Decorated ’ that England had given up a century and a half earlier. The stone carving in the chapel too is very much in the ‘ Decorated ’ manner. While the windows are ‘ curvilinear ’ and ‘ flowing ’ in character, the proportion of the cusped trefoil heads of the lights is peculiar ; and the pointed window arches are really four-centred, although instead of being ‘ depressed ’ arches they are the reverse. The partiality shown for unusually large centre mullions which run up to the head of the arch is not easy of satisfactory explanation. The buttress system might be supposed to indicate stone cross-vaulting ; but at that time vaults built in Scotland were usually pointed barrel vaults, upon the surface of which purely ornamental stone ribs appeared. These stone barrel vaults were barbarous and ponderous, and very detrimental to good lighting. Bishop Elphinstone, at his College Chapel (as at the choir of St. Nicholas') adopted a ceiling that in effect is a very low wooden barrel vault. On the north wall outside there may be seen parts of five of the twelve Consecration Crosses. Inside the chapel two of the pre-Reformation black-marble altar slabs have been preserved, owing to their having been used as grave slabs for university officials who died respectively in 1593 and 1601.

The twin freestone spires of St. Machar's were built on Bishop Lichtoun's granite towers in Bishop Dunbar's time (1518–32) ; and probably the battlements were altered and reduced in height at the same time. In the south transept are two elaborate wall-tombs, arched and canopied. Bishop Dunbar's, the earlier, may have been built before his death (1532).

The bridge over the Dee at Ruthrieston, a ribbed structure of seven nearly semicircular arches, was built (*c.* 1520–27) for Bishop Dunbar and under his clerical Master of the Works, ‘ Maister Alexander Galloway, Persoun of Kynkell,’ by Thomas Franche, master-mason, the son of a master-mason, John Franche, who died at Linlithgow in 1489. Thomas Franche was engaged on the Bridge of Dee and the rebuilding of the south transept of St. Machar's, and probably on the other work built for the Bishop, from about 1520 until 1530—possibly later. He is found at Linlithgow as the King's master-mason in 1535, and in the same capacity at Falkland in 1537–38.

There can be no doubt that to Thomas Franche the design and execution of the architectural work of his period in Aberdeen must be attributed: that is to say, Thomas Franche was what we now should call the 'architect' of these works.

The carved oak stalls of King's College Chapel are its greatest treasure. Without doubt a large part of the stall work, including all the canopy work, is Flemish. The extraordinary number and variety of the traceried patterns is without a parallel in this country, while the craftsmanship is remarkable for vigour and freedom. It will be observed that in the repairs made last century a number of the traceried canopy units have been pieced together, one smaller and slightly mutilated traceried pattern above another of the same being required to fill a whole panel. Apparently these smaller traceried heads originally belonged to the panelled stall-backs which have all been renewed in plain panelling. The present loft for the organ and choir retains three high canopies, an ambo, and some other parts of the original rood loft, besides the screen and door.

While the greater part of the carved-oak work was brought from Flanders, there is reason to believe that much of the heavier and simpler work may have been done by local wrights. The Council Register of the Burgh records some works on which a certain John Fendour was engaged; in 1495 he was paid 'for the making of the ruff and tymmir of the queyr' of St. Nicholas'; in 1507 he entered into an agreement to build thirty-four stalls, 'with the spiris and the chanslar dur' in the same choir. Some parts of Fendour's canopies, and other pieces of his carving from St. Nicholas', may be seen in the National Museum of Antiquities in Edinburgh; and other pieces of his work are in St. Mary's Chapel and elsewhere in Aberdeen. A study of these proves that while the stall canopies of St. Nicholas' somewhat resembled those of King's they were distinctly different, but that much of the simpler work at both churches was identical. It may safely be concluded that John Fendour was employed on the stalls of the College Chapel. And possibly he was responsible for the ceiling there; for from what we know of Fendour's ceiling of St. Nicholas' choir it must have closely resembled the ceiling of the College Chapel, a very large part of which is ancient, including all the carved bosses and much of the traceried eaves-fringe. The effective black-line painted close to the ceiling ribs and foliaged cross-arms is a restoration of the original treatment.

Another work by John Fendour for Bishop Elphinstone was the 'tymmer werk' of the great central steeple of St. Machar's, a lead-covered spire that was destroyed during the Reformation troubles. The contract with 'Johnne Findour wrycht' is dated April 18, 1511.

The latest Gothic ceiling in Aberdeen is that of St. Machar's, done in Bishop Dunbar's time. It is of oak, fixed to the underside of the level roof-ties which are placed at about 4 ft. above the eaves; so that a deep frieze, leaning slightly inwards, runs round the church between the eaves and the level ceiling. The frieze is divided into panels—three to each ceiling compartment—by a series of crocketted pinnacles, and decorated with traceried fringes and a continuous black-letter inscription. The

flat ceiling is divided into sixty-eight compartments by moulded ribs, and each compartment again into four severies by subordinate diagonal ribs having bosses at the intersections and foliaged cross-arms. At the crossings of the main ribs forty-eight heraldic shields are marshalled in three lines from east to west. The centre row begins with the reigning Pope (Leo X, 1513–21) and continues with the Archbishops and Bishops of Scotland; the northern row begins with the Emperor (Charles V) and continues with Kings; and the southern row with the King of Scotland (James V), followed by Scottish nobles. The ceiling, which was probably devised by Alexander Galloway, dates from the early years of the second decade of the sixteenth century. Referring to it, William Orem, Town Clerk of Old Aberdeen, writing early in the eighteenth century, says, 'James Winter, an Angus man, was architect of the timber work and ceiling of said church.' Although Winter is a surname not unknown in Angus, it is possible that Findour should be substituted for Winter. Findour, or Fendour, may be a name of French origin (? Fendeur).

An example of local carved-oak heraldic work, rather later than the ceiling of St. Machar's, forms the front of the chancellor's desk in the Mitchell Hall, Marischal College.

The oak pulpit in King's College Chapel bears the arms (twice) of Bishop William Stewart (1533–45), but only the carved panels (or most of them) are ancient; they were parts of a decayed old pulpit, at one time in St. Machar's, incorporated in this much-altered version of the original, known to us from James Logan's careful drawing.

A Flemish Gothic chair, very richly traceried, and a valuable collection of Aberdeen carved chairs and other furniture of the seventeenth century, the property of the Incorporated Trades, are housed in Trinity Hall. Much interesting carved woodwork of the seventeenth century, from the old west and east churches of St. Nicholas, is to be seen in St. Mary's Chapel.

Castle-building.—Kildrummy Castle, a work of national rather than of provincial importance, having been exhaustively treated in Dr. W. Douglas Simpson's monograph, needs only to be here mentioned as the oldest and the greatest of Aberdeenshire castles.

The other castles of the district are so numerous and diverse and in such various states that in this survey it seems best to concentrate on one or two typical examples in good repair.

The oldest and the most interesting castle near Aberdeen, fit for occupation and still partly occupied, is the Tower of Drum, roughly $40\frac{1}{2}$ by $51\frac{1}{2}$ by 70 ft. high to the top of the battlements. The walls are 12 ft. thick at the bottom and 8 ft. at the height of 50 ft. Built of roughly concreted granite rubble, with its four corners well rounded, the tower contains three storeys, each being vaulted with a pointed barrel vault. On the top is the battlemented stage, with its pathway surrounding the garret—a house measuring 28 by 40 ft. The battlemented parapet walls are high and thick, battered, and oversailing a little. The small corbel course under the parapet is the only moulding on the tower. No machicolation occurs, except at a latrine, corbelled out from the pathway. The planning and construction are archaic, but carried out with high efficiency

by a master of his craft. The use of sandstone is confined to the winding-stair steps and the jambs and arch of a fireplace, distinctly Early English in style.

It is impossible definitely to fix the date of Drum Castle. The Forest of Drum, one of the royal forests, was erected into a free barony for William de Irvin in 1324, and it is believed that the castle existed before that date. Richard Cementarius, the King's master-mason, was in 1272 alderman of Aberdeen—the earliest recorded name in the line of aldermen and provosts—and survived until about 1294. His work in the North of Scotland could hardly have been confined to the castle of Aberdeen ; and circumstances connected with him suggest that he may have been engaged on the old Bridge of Don, which was built from bishop's revenues in the time of Bishop Chein (1285–1328). An elevation of the bridge is very like the cross-section of the third storey of Drum Castle ; and although the building of the bridge was interrupted, and not finished until long after Richard's death (and when done, it was credited to King Robert the Bruce rather than to Chein), it is probable that Richard Cementarius built Drum Castle and began the Bridge of Don. It is true that Drum Castle might have been built by Bruce after 1314 and before 1324 ; but a date before the death of Alexander III in 1286 seems on the whole to be more probable. In any case, the tower of Drum, if only in virtue of its material, seems to represent an Aberdeenshire type which influenced the technique of our later castles.

The transference of much wealth from the Church to the lairds was the occasion of a great activity in house-building that culminated about 1620, and did not quite die away until the end of the seventeenth century. Whether again it was of necessity or not, these new Aberdeenshire castles were built by local masons, of granite, unless where a sandstone quarry was near. Among the most notable examples are Craigievar, Crathes, Midmar, Castle Fraser, and Drum. The manner of building, the architectural detail and decorative elements are common to all ; but almost every castle shows distinctive and individual character. That the ground-plans are so various is the root cause, each type of plan leading to its own characteristic masses and groupings. The simple oblong plan developed into L plans of various kinds ; later, under the influence of planning for defence by firearms, the stepped plan was invented, in which either two or three blocks were joined together on a diagonal line, i.e. *en échelon*. Craigievar and Crathes show different modifications of the L type ; Midmar and Castle Fraser are of the three-stepped type ; while the House of Drum (1619), connected to the ancient tower by a short wing is, with excellent judgment, planned as a long and comparatively low block between a pair of small square blocks which project forwards and are tacked on to the main block, ' corner to corner,' as in the stepped plan.

Midmar and Castle Fraser were built by members of a local family of masons named Bel. Castle Fraser, which perhaps is the most representative of the group, was signed by I. Bel, master-mason, 1617, just when it was nearly finished, as first designed.

Common to all these castles is the battering of the rubble walls, some-

times with a suggestion of entasis ; the free and occasionally fanciful use of corbelling, the units of which hardly vary in profile ; and the corner ' rounds,' or turrets, from which shot could be directed ' alongst the walls.' These ' rounds ' are seldom quite circular on plan, but slightly oval or in a succession of planes ; they project very little over the corner of the supporting walls, and are carried up leaning backwards towards the parent body. It would almost seem as if the walls and turrets had been modelled rather than built, so sensitively are the planes adjusted to each other. Both at Midmar and Castle Fraser one of the end blocks is circular and carried up higher than the others ; its staircase turret is taken still higher, and finished with an ogee roof, a stang and weathervane.

The dead forms of medieval machicolation corbelling and battlements were adapted at Castle Fraser to serve other uses : the medieval machicolation corbels have shrunk into a purely decorative corbel table or cornice, whose architectural use is to tie the three blocks together, jumping down and up again to embrace the turrets.

The pseudo-parapet is found right under the eaves of the roof, the pseudo-embrasures forming windows, which are carried up into the roof as stone dormers. But many of the smaller castles are quite free from such vestigial marks : they fulfil in the most direct way all structural and other needs, under a due sense of the nature of granite and an instinct for fine form.

Freestone on the walls of Castle Fraser is confined to heraldic panels ; and its use elsewhere in granite castles does not go beyond such small things as gargoyles and bits of carving.

The Seventeenth Century in Aberdeen.—In the town of Aberdeen during this period stone dressings for buildings continued generally to be of freestone, and towards the end of the century much competent work in freestone cutting was produced—tombs and monuments, heraldic shields and cartouches, and the hexagonal Market Cross (1686), designed and built by John Montgomery, a mason from Rayne in Aberdeenshire.

Provost Sir George Skene's house in the Guestrow, with fine plaster ceilings, woodwork, ironwork, and decorative painting, is about the last town-house of the period left in Aberdeen.

The Eighteenth Century.—The eighteenth century saw the building of Gordon's Hospital (it is said, from plans by William Adam) ; and, on the site of the Middle-Pointed nave of St. Nicholas', the present West Church (1755), in stately Roman style, carried out in freestone from Fife, above a granite plinth, from plans by the architect James Gibbs, an Aberdeen man born and bred.

Shortly after ' the Forty-five,' granite ashlar houses began to appear in Gilcomston, then a suburb, and in the town ; dates in the fifties and sixties, still to be seen, show when and where the development took place.

A gateway to St. Paul's, Gallowgate, designed in a rather homely but interesting Classic manner, shows that the art of masonry in granite was not entirely neglected at the time when the West Church was new.

About 1772, after a disastrous fire at King's College, parts of the south wall of the chapel and of the east wall of the steeple were faced with excellent granite ashlar, whose ' cherry-cocked ' pointing still remains

intact. About the same time two manses for professors were built of granite, in College Bounds. These works and the older houses in Marischal Street which was formed in 1767 mark the beginnings of modern granite masonry in Aberdeen.

Duff House and Haddo House, works by William Adam of Maryburgh, father of Robert Adam, were carried out in the Renaissance tradition, with freestone dressings; Duff House especially may be considered extraneous. Cairness House in Buchan, built of granite towards the end of the century (1799) from designs by James Playfair, a London Scot, and said (*c.* 1810) by Dr. Skene Keith to be 'the largest and the best house belonging to any private gentleman in the county,' shows originality and much refinement, with some not unpleasant touches of eccentricity; Cairness seems to have had some effect on the development of Classic in the North.

THE NINETEENTH CENTURY.—In Aberdeen itself, the Bank on the south side of Castle Street (1801) was designed by James Burn of Haddington, and built of granite in the Classic style of which Chambers was the last great exponent.

The building of Union Bridge over the Denburn, originally entirely a granite structure which was finished *c.* 1805, opened the way to the expansion of Aberdeen westwards. The granite house of Mr. Milne of Crimonmogate—now the Royal Northern Club—was the first to be built west of the bridge and the earliest architectural work of John Smith (1781–1852).

That Aberdeen during the course of the nineteenth century came to be familiarly known as 'the Granite City' is owing, firstly, to the enterprise of those who quarried the material, of whom John Gibb, civil engineer and quarrymaster, was chief; and secondly, to two architect sons of Aberdeen, the earliest regular practitioners of architecture resident in Aberdeen—John Smith, already mentioned, and Archibald Simpson (1790–1847), whose taste, skill and scholarship in the adaptation of Classic forms (the vogue of their time was Grecian) to modern uses, in buildings carried out in hard crystalline granite, was as remarkable as their success in training a school of craftsmen unrivalled for the accuracy and beauty of their work. Among John Smith's works were the North Church in King Street (1830); the screen to St. Nicholas' Churchyard in Union Street (1830), and Prof. Hamilton's monument, adjacent (1833); and 'The Town's Schools' in Little Belmont Street (1841). Among Archibald Simpson's works were the Assembly Rooms (1820), now the front part of the Music Hall Buildings; the older part of the Royal Infirmary (1838); the North of Scotland Bank in Castle Street (1842); and the Market in Market Street (1842).

'Gothic' in the hands of these pioneers of modern granite building fared but poorly. It has happened, however, that Simpson's Marischal College (1838–42) lies behind the façade of the New Buildings by Alexander Marshall Mackenzie (1848–1933), whose handling of Kemnay granite in 'Perpendicular Gothic' is as attractive as the 'Gothic' of a hundred years ago is dull.

The architecture of Aberdeen between then and now must speak for itself.

PICTISH SYMBOLISM AND THE SCULPTURED STONES OF NORTH-EAST SCOTLAND.

BY

W. DOUGLAS SIMPSON, M.A., D.Litt.

UNDOUBTEDLY the most distinctive subject of archæological study that the North-east of Scotland offers is its mysterious Pictish symbolism.

In not a few respects the Picts were a remarkable race : most of all in the unique development of symbolic art which characterised their sculptured monuments during the period of the Celtic church. Under a set of influences and with an evolutionary origin alike wholly unknown to us, there was then developed among the Picts of the North-east a highly elaborated, rigidly conventional and extremely artistic code of symbolism, to the meaning of which no key has yet been discovered. This symbolism is marked by two significant characteristics. Firstly, save for a few stray ' outliers,' it is entirely confined to the districts known to have been inhabited by the Picts ; and within these limits it is overwhelmingly a product of the eastern lowlands. Secondly, the forms of the symbols wherever they are found, from the Shetlands to Galloway, and from Aberdeenshire to the Outer Isles, are so highly standardised that it is clear we have to deal with a fully articulated, well-understood and widespread system of ideographic art, the invention of which must be accounted an astonishing manifestation of the Pictish genius.

Comparative study of these monuments shows that they fall into three classes, and it has been found possible approximately to delimit the chronological horizon of each class.

Class I (before A.D. 800) : Unshapen and undressed monoliths with incised symbols only. Of these, fifty-four examples are known in the district between the Dee and the Spey—well-nigh half the total number of this class recorded in Scotland.

Class II (about A.D. 800–1000) : Slabs roughly tooled and shaped, bearing in addition to the symbols a cross of Celtic pattern, and often elaborate figure groups ; the sculpture now being in relief, and the symbols and cross alike enriched with more or less complex ornamentation in the school of Celtic art. This class is represented in our district by seven examples, two of which have ogam inscriptions.

Class III (from about A.D. 1000 to the extinction of native Celtic art by the Anglo-Norman infiltration in the twelfth and thirteenth centuries) : Slabs in which the symbols have now disappeared, so that there remains only the Celtic cross, carved in relief and often sumptuously decorated. At least sixteen examples occur in our district. It is not always possible to say whether certain plain crosses belong to the Celtic period or later.

Whether the symbols were in their origin pagan or Christian is disputed. All that can be said meantime is that the associations of the symbols, where determinable, are always Christian. Stones of Class I occur again and again at known early Celtic church sites ; and even

where they have no such association, we must remember that on the spot may once have been a primitive chapel, all knowledge of which may have perished. One case, however, occurs where symbols are incised on one of a group of two standing stones assignable probably to the Bronze Age : but here the symbols may be secondary. It is at all events clear that the symbolism was capable in its entirety of bearing a Christian meaning, as is shown by its association with the cross on the monuments of Class II. The symbols have also been found inscribed on objects of metal and bone, and rudely carved on natural rock surfaces. In no authentic case has one of the symbol stones been found in connection with a burial.

Equally mysterious is the sudden way in which this symbolism blossoms forth as a fully developed and highly elaborate art. Even in Class I stones the symbols appear as a mature, systematic and determinate hieroglyphic *corpus*, which must surely have had a long evolutionary history behind it. But of its more primitive stages nothing is known. It is a mistake to imagine that the rude representations of the symbols cut or scratched on the walls of certain caves represent such an earlier stage of development, for the symbols on the monuments are clearly the work of skilled carvers trained in the conventions of their art, whereas those found in the caves are the amateur *graffiti* of hermits.

The distribution of these monuments in their three classes presents some interesting problems. By far the greatest number of Class I occur in Aberdeenshire, and specially in the Lower Garioch, so as to suggest that the symbolic art may perhaps have originated in this area. When we pass into Class II the focus shifts southward into Angus. This may be due to the fact that the soft sandstones below the Highland boundary fault are more suited for the elaborately carved stones of this class than are the intractable granites and schists of the Mearns and Aberdeenshire.

The names commonly given to the symbols are merely convenient labels. It seems hard to believe that the ' mirror ' and ' comb ' symbols can represent anything else than these articles, whatever their symbolical import. On the other hand, it is impossible to say what the so-called ' elephant,' the ' double-disc and Z rod,' the ' crescent and V rod,' or the ' two-legged rectangle ' are intended to portray. The animal forms suggest affinities with the early Christian Bestiaries. About fifty different symbol forms are known, and the way in which various combinations recur is significant.

X.

PREHISTORIC ARCHÆOLOGY IN ABERDEEN DISTRICT

BY

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THE following account refers to the part of the North-east of Scotland composed roughly of the counties of Aberdeen, Banff and Kincardine.

In that area there is no evidence that can be definitely associated with Palæolithic man, but in it, however, there are traces from which an idea may be arrived at of the physical appearances, habits and culture of the people inhabiting it during the late Mesolithic and the subsequent Neolithic period, which is "generally believed to have ended in this country about 2000 B.C., and during the Bronze Age, which extended probably from about 2000 B.C. to 500 B.C." It must be understood, however, that these periods, which are largely cultural, are not sharply separated from one another, but overlap to a considerable extent. The traces are chiefly interments and artifacts which have been found scattered irregularly in the soil.

MESOLITHIC AGE.—As regards the Mesolithic Age, the only traces which are found of the inhabitants are small finely chipped implements of flint about ¾ in. long and known, because of their small size, as 'pigmy' flints. These have been found in fields near old river terraces in Banchory Ternan on Deeside in Kincardineshire. Their use is a mystery, but it has been conjectured that they were hafted to serve as knives, employed as teeth for saws, or used as gravers, borers, etc.

NEOLITHIC AGE.—In the Neolithic Age, no traces of man beyond his artifacts have been found, unless it should prove that certain long cairns found at Longmanhill, N.B. Gamrie, Banffshire; Balnagowan, Aboyne; Newhills, Aberdeenshire; and Gourdon, Kincardineshire, belong to this age. These include pottery, implements in flint and stone, characterised by their fine shape and careful finish, which pass into the succeeding Early Bronze Age. The vessel from Craig, Auchindoir, Aberdeenshire, in the Anthropological Museum at Marischal College, is a good example of the pottery of the age. In addition to this vessel the only remains of such Neolithic pottery as yet recorded from this district are fragments of urns from Knapperty Hillock, from Finnercy, Echt, and from Ferniebrae, Chapel of Garioch, all in Aberdeenshire.

BRONZE AGE.—*Short stone cist interments.*—It is when the Bronze Age is reached that evidences of man and his works become abundant. The most interesting of these are the short cist interments, concerning which

it has to be noted that they contain the earliest human skeletal remains that have yet been found in the district. These are distributed irregularly, but sometimes they are in groups, as in the parishes of Dunnottar and Kinneff in Kincardineshire. In the majority of cases no mounds or monuments or external marks indicate their situations. In some instances, however, they have been found in mounds of earth or sandy gravel, or covered by cairns of stones, and in one case within a stone circle at Crichie, Aberdeenshire.

In the Aberdeen University Anthropological Museum there is a collection of the contents of cists, individually displayed. Besides these, there are three cists, one of which is placed in the Anatomical Department, mounted to show the manner in which they were constructed as well as their contents in their position as found. These may be taken as fair examples of the Bronze Age burials in the district.

The cists in which the remains were found were roughly rectangular, the inside measurements being on an average about 3 ft. 8 in. long, 2 ft. broad and 1 ft. 8 in. deep. They lay from 6 in. to 2 ft. below the surface of the ground, and the walls and roofs were formed of rough, flattened stones similar to those in the vicinity. The roofs consisted of one main flat stone, but occasionally there were several, as in a cist found in Kinneff in Kincardineshire and now in the Aberdeen University Anthropological Museum. The roof of this cist is also of interest as it consists of many slabs arranged in three layers, the under surface of one of these stones bearing rude sculpturing and evidence of atmospheric weathering before the stone was used to form the roof of the cist. Another of these roofing stones shows an artificial perforation countersunk on both sides.

The floors of the cists were formed either of the gravelly stratum upon which the cists stood, or were paved by small, water-worn stones or by a thin layer of clay into which pebbles had been inserted.

As regards their orientation when recorded, the long axes were directed from west to east, from south-west to north-east or from south to north, and it is interesting to observe that the skeletons were found in a crouching position with the knees bent, the thighs directed towards the front of the trunk, and the head of the skeleton usually lying in the north or north-east end of the cist.

From an examination of 48 skeletons, a few of which were from other parts of Scotland, 31 were male and 17 were female. The average age of the males was about 50 years and that of the females about 40 years, and it is observable, therefore, that, for some reason or other, the lives of their owners had been comparatively short. The males were short in stature, on the average about 5 ft. 5 in., and the females about 5 ft. 1 in. As regards cranial capacity, the male skull showed an average of 1,438 cc., the female 1,368 cc., and when compared with the average capacity of the skulls of modern Europeans (1,500 cc.), both were considerably less. The skulls of these people were broad, but not very much so. Their foreheads were full and the brow ridges not particularly raised. Their faces were broad and short, the sockets for the eyeballs narrowed from above downwards, the noses wide, the jaws projecting no farther forward

than they do in present-day inhabitants, the cheek bones fairly prominent, and the teeth healthy but in most cases worn down, in all probability by the use of coarse and gritty food.

The bones, especially those of the limbs, showed that, while of low stature, the people had been active and muscular, and it is interesting to observe that the remains of their lower extremities presented appearances which are visible in the inferior races of mankind of to-day, whose lower limbs are shaped in order to allow of firm grasping and rapid barefooted movements. Some of these remains also suggest the idea that the individual may have assumed a squatting position when at rest, and may have walked with the knees somewhat bent. With the exception of a few traces of the effects of rheumatism in one spine, the remains of the skeletons in the Museum showed no signs of disease or injury.

The origin of these people is veiled in obscurity. It is considered that the type migrated from Central Europe, bringing with them to Great Britain their beaker-shaped pottery and a knowledge of copper. This view that the type came from Central Europe is corroborated by the close resemblance between it and that of the Czechs and Rumanians, as shown by an anthropometric comparison of their skeletal remains.

In addition to the skeleton, short cists in most cases contained rude vessels of clay usually spoken of as urns. As a rule one vessel was contained in a cist, but sometimes two or, very rarely, three were present.

From their shapes they are ordinarily described as drinking cups or beakers, and food vessels. They are composed of coarse clay mixed with sharp, sandy, gritty material, and each one exhibits the effects of the action of fire. They are of a brownish colour which varies in shade according to the clay which had been used. They are ornamented by incised lines, cordoned and maggot-shaped designs, usually in such a way as to form herring-bone and other angular patterns. The ornamentation exists upon the outside of the vessels, rarely on the edges of the lips, and still more rarely upon the inner surfaces of the lips. "Each drinking cup has a slightly constricted neck, an expanded mouth, and a bulging body, and varies from about 5 to 8 in. in height, its breadth being always less than its height. The food vessel is usually not so high as the drinking cup. It has no constricted neck or expanded mouth and is more or less globular in shape." Nothing beyond a small quantity of sand, which had no doubt gained admission by accident, was found in any of these vessels. As to their purpose it can merely be suggested that they contained food or other nourishment for the deceased, and this suggestion would point to a belief in existence after death.

Beside the skeleton from a cist found at Clinterty, Aberdeenshire, displayed in the University Museum, there lay an axe in mica schist, five scrapers in flint, two barbed arrow-heads in flint, a crystal of topaz, a pointed and perforated bone implement, and an imperfect ring in bone which was perforated in such a way that it had probably been used as an amulet. A short cist at Tullochvenus, Aberdeenshire, contained in addition to an urn and burnt bones a tanged razor blade in bronze which is now in the University Museum. There have been described as found in other cists objects such as bronze rings, horn spoon or ladle, piece of

ox-hide, a polished stone hammer, bones of boar, etc. Small pieces of charcoal have sometimes been found both in the cists and in the soil surrounding them, and since the bones in the cists had not been cremated, it is probable that fire was used in the funeral rites of those people.

The method of interment by inhumation did not cease abruptly, but gradually merged into burial after cremation. A cist was exposed at Fyvie, Aberdeenshire, which contained an urn of the drinking-cup type, along with ashes of bones lying loosely on the floor of the cist and not inside the urn. Another cist, now in the University Museum, was found at Auchlin, Aberdour, Aberdeenshire, in which human skeletal remains were found which had been subjected to the action of fire, along with the remains of a child's skeleton which had not been burned, and pieces of charcoal.

Cremation or cinerary urns are of a larger size than those usually found in short stone cists. They are unglazed, made of a coarser pottery and badly fired. In most cases their shape is that of two truncated cones united at their bases—the cone which enters into the formation of the mouth forming the smaller part of the urn. The ornamentation, which is mostly confined to the upper part of the urn, consists of horizontal and wavy ridges; discs and bosses; horizontal, vertical and oblique lines; and circular indentations about a quarter of an inch in diameter which are to be found in the neighbourhood of the mouth. From their appearances they are classified as overhanging rim urns, cordoned urns, and encrusted urns, examples of which, found in Aberdeenshire, are to be seen in the Anthropological Museum at Marischal College, Aberdeen.

This class of pottery has been found in many parts of the district and in various situations. Sometimes the urn is merely placed in a cavity of the ground without any indication on the surface of its presence. In other cases the interment was within the area of a standing stone circle, or sometimes under a cairn. The usage as regards the calcined bones varies. At one time the urn is inverted over them, at another it is placed on its base and contains them with a flat stone laid over the mouth. Along with the bones there frequently occur ornaments in gold and other substances, as well as implements and weapons in bronze or stone.

Associated with the burning of the dead and sometimes placed within cinerary urns are the diminutive and ornamented vessels known as 'incense cups.' The name is, however, purely conjectural. The only example from this district, which is now in the University Anthropological Museum, is not of the perforated variety, but shows a loop supposed to be for suspension. It was discovered on the surface of the ground on the Hill of Keir, Skene, Aberdeenshire, with an ammonite inside it and a flint arrow-head near by.

Stone circles.—Perhaps none of the archæological remains which the district yields are so well known as the circles of upright stones which are commonly called standing stone circles or Druid circles. They consist of upright monoliths which vary in number and are arranged in a circular manner.

The simple circle, the most common form, may be divided into two classes according as it does, or does not, possess a 'recumbent' stone.

This prominent block, which may weigh several tons, is placed between two large upright monoliths, and lies in the southern arc, opposite the northern aspect of the circle. The stones composing the circle diminish in size from the monoliths supporting the recumbent stone to those in the opposite arc of the circle. A remarkable fact in connection with this is that the recumbent stone is peculiar to the circles in Aberdeenshire and immediate neighbourhood. Other circles have within them one or two concentric circles, the stones of which are smaller in size.

Sometimes a causeway or an avenue of large stones arranged in two parallel rows is found leading to or from the circle. An example of the latter is seen at Crichie, Aberdeenshire.

The diameter of a standing stone circle varies from 10 ft. to more than 100 ft., and the size of the stones has a wide range of variation. Some are no more than 2 ft. above ground, while the largest may be more than 10 ft. The individual stones are rough undressed boulders from the rock of the neighbourhood, or are ice-borne erratics. Inscriptions are totally absent from them, but ' cup markings ' are common. On one of the stones of a circle at Nether Corskie, Echt, Aberdeenshire, the well-known symbols of a mirror case, mirror and comb occur, which symbols are found elsewhere in abundance on stones not belonging to circles. It seems better to assign these Corskie sculpturings to a later date than the circle itself.

There are approximately 145 sites of stone circles in Aberdeenshire alone. Examples of circles in a good state of preservation may be mentioned at Sunhoney, with another near it in the Midmar graveyard ; at Dyce ; and at Auquhorthies near Inverurie—all in Aberdeenshire A stone which is to be seen at the junction of Langstane Place and Dee Street on the left-hand side of Union Street, Aberdeen, is believed to have formed part of a circle.

Upon looking at the district as a whole, the circles are mostly to be found in the river valleys, particularly in that of the Don, where no fewer than 52 sites are known, a fact which indicates that the weight of the population existed there owing to the superior fertility of the soil.

Many theories have been advanced as to the origin and significance of these antiquities. It is, however, an ascertained fact that they were used for sepulchral purposes, as incinerated human remains of the Bronze Age period have been found within them. Apart from this, any use assigned to them is somewhat conjectural.

Besides these circles of standing stones there are also examples of solitary monoliths concerning which there is no record of their having formed part of a circle, and which from their position are unlikely to have done so. Some of these are of great height.

Cup-marked stones.—The practice of inscribing small cups or hollows, or groups of them, on stones, which is familiar all over the British Isles, is also a well-represented feature of the prehistoric archæology here. These depressions vary in size from about 2 to 3 in. in diameter and in depth from ½ to 1 in. In some cases the cup is surrounded by a concentric ring, rarely by two. In this district these markings occur most frequently

on stones which form part of stone circles, being especially present on the recumbent stone or stones near it. They are found also on solitary standing stones, boulders and rock surfaces.

No explanation of what was intended by these markings seems to have been able to secure general acceptance.

A cup-marked boulder which was found a short distance from the site of the cist at Kinneff described on p. 69 may be seen in the Museum.

Cairns.—These structures are of all sizes, from about 10 ft. in diameter up to about 100 ft. The great majority are circular and the height of the pile varies from 1 to 2 ft. to about as high as 40 ft. As to their position it has been noted that they are more commonly found at or above 700 ft. above sea-level than below.

Compared with these circular cairns, long cairns are much fewer in number, but from the records available regarding them it is unsafe to assign them to any particular age, as none of them seem to have been examined by excavation. Examples of these long cairns are seen at Gourdon, Kincardineshire; Newhills, Aberdeenshire; Longmanhill, Gamrie, Banffshire.

Considerable uncertainty attaches also to those of circular shape. It has of course been definitely ascertained in many cases that human interments took place within them in the Bronze Age, but others have often been found to yield nothing. It is not necessary to suppose that they always served the same purpose. Some may have been beacons or memorials of events, etc.

No enumeration of cairns is available for the whole district, but general inspection shows that they are present more or less everywhere. Cromar district in upper Deeside, measuring about eight miles from east to west and six miles from north to south, most of it being more than 600 ft. above sea-level, has been particularly examined, and many hundreds have been recorded.

Hut circles.—These are commonly found in the neighbourhood of cairns, or definitely associated with them. They consist of loose stones, rather larger in size than those used in cairns, the rings rising as a rule not more than 2 ft. above the present ground surface. The diameter is often about 12 to 20 ft. In most cases the natural ground forms the floor of the circle, but sometimes a paved surface is present.

The general appearance of these structures, along with the fact that they often occur in clusters and that there has been discovered within them such objects as flint arrow-heads, stone discs, charcoal and ashes, suggests that they are the remains of prehistoric habitations.

In the Kinnord and Dinnet area of Aberdeenshire many examples of these circles, along with other prehistoric remains, can be seen. A group of eight circles exists at Skene's Wood, Fintray, Aberdeenshire.

Sporadic finds.—Besides the artifacts mentioned as occurring in graves or associated with other structures, by far the greater number of such objects are single 'finds' casually picked up on the surface of the ground.

As regards implements in flint, arrow-heads of various forms—leaf, lozenge, barbed and tanged—have been found abundantly. They were used not only in Neolithic times, but since no bronze arrow-head has ever

been found in Scotland, it may be inferred that they continued in use during the age of bronze.

Other objects in flint are scrapers, saws, knives, amulets, fabricators, cores, etc. The exceptional abundance of these objects in the North-east is to be explained by the fact that in Buchan in Aberdeenshire there is an extensive area, stretching inland from near Boddam for about ten miles, in which natural flints are plentifully found.

Prehistoric flint workshops have been located at the seaside at Menie, Belhelvie, about seven miles north of Aberdeen, and farther north at Forvie sands near the mouth of the river Ythan, whose existence is suggested by quantities of flakes, cores and waste products, together with hammers, anvil stones and unfinished flint implements, having been found there.

Implements in stone comprise axe-heads, hammers, cups, smoothing stones, amulets, whetstones, perforated discs, anvils, querns, stone lamps, socket stones, sinkers, whorls, mortars, etc. As in the case of flint arrow-heads, all artifacts in stone do not necessarily belong to Neolithic times, but some extended to a later period and any particular specimen has to be considered as to dating upon its own merits. The ornamented stone balls, which are believed to be peculiar to Scotland, and whose use and date are conjectural, are well represented in the district. The artistic merit of some of the more highly finished of this type of ball suggest a date not long before or even within the historic period.

Objects of bronze found in the district are leaf-shaped swords, scabbards, dagger-blades, spear-heads, and different varieties of flat, flanged and socketed axe-heads, bronze harness mountings, sickles, etc.

Objects of personal adornment are not infrequent. They are commonly armlets of elaborate design, sometimes with enamels inset. In this connection beads may be mentioned, which though not of bronze are articles of adornment. They are made of many varieties of stone and of paste, the latter decorated with the same spiral design which is found on the bronze amulets.

Specimens of most of the objects referred to in this section are to be seen in the University Museum.

Iron Age.—*Earth houses.*—These structures are found sporadically from Berwickshire to Shetland, especially in the east, but here they occur more plentifully. In the parishes of Auchindoir and Kildrummy, Aberdeenshire, a group of about fifty have been recorded in recent times within an area of two square miles. Again, not far off, in the Cromar area, no fewer than seven have been noted.

The typical Scottish earth house, in the older vernacular ' yerd hoose,' is invisible from the surface of the ground, though the roof is within a foot or two of it. This is how they appear when discovered to-day, but when in use the entrance leading into the chamber was of course exposed. The underground tunnel has walls made of undressed stones, without mortar, which converge as they rise and support the massive flat stones laid across them to form the roof. One or two specimens have been found with perpendicular walls, from which, and from the absence of the roofing stones, a wooden roof can be inferred. The entrance is narrow

and the passage leads downwards in a sloping fashion to the floor of the chamber. The latter is always more or less curved and increases in height and width towards the far end. There are often side chambers, or 'ambries,' leading off from the main tunnel. A common length for the whole chamber is about 50 ft., greatest breadth about 6 to 8 ft., and height 5 or 6 ft., sometimes more. The floor is usually earthen, but in one case, at Buchaam, Strathdon, Aberdeenshire, it is paved over the whole area and not merely at the entrance, as is sometimes found, and a well-built stone drain, 10 in. square, leads from it. Smoke holes in the roof have been observed in a few.

An approximate date for these structures can be arrived at from a consideration of the contents that have been recovered from them. These include objects in bronze, especially articles of ornament; bronze needles; objects in iron, being subject to oxidisation, have mostly disappeared, but the presence of such articles has been definitely ascertained in many cases; rude pottery, but also some wheel-made; querns; bones of the domestic animals; horns of deer; staves of wood. It is evident from this that the earth houses were used and inhabited in the Iron Age, and there is direct proof that the date can be brought down as low as the early centuries of our era. Some of the bronze ornaments referred to above are particularly fine examples of late Celtic art. They occurred in earth houses in the parish of Coull, Aberdeenshire, and at Castle Newe, Strathdon, in the same county. The latter also yielded a coin of the Emperor Nerva (A.D. 96–98) which supplies an authentic date. But the question of how early these constructions came into use is harder to determine; probably the late Bronze Age is the earliest date that could be assigned.

It is most likely that hut habitations of a less permanent character were erected over or near these houses. In two cases in this district indications of this arrangement still remain, viz. at Loch Kinnord, Aberdeenshire, and at Milton of Whitehouse, four miles north of the loch. In both of these cases there are stone pavements close to the entrance which show early hearths with charcoal remains, and on which burnt bones, part of a quern and an angular piece of iron were found.

Good examples of the earth houses of this district may be seen at Muirs of Kildrummy, near Kildrummy Castle; near Glenkindie House; Buchaam, Strathdon; at Culsh, Tarland, and at Migvie, west of Tarland—all in Aberdeenshire.

Lake dwellings.—Associated chronologically with the earth houses are the crannogs or lake dwellings of Scotland; they yield the same kind of relics and belong to the Iron Age. Some are shown, from the archæological material discovered in them, to have been in occupation in the early centuries of our era. The method of constructing these places of security has been ascertained, when from drainage or other causes the lochs in which they were situated became dry and they could be systematically examined. The procedure was as follows. On the surface of the water a raft was constructed composed of logs mortised together, on which stones and earth and branches were piled, with beams as the work proceeded, and thus, as the added material gradually accumulated, the whole mass finally grounded. The result of such a plan of building has

been that islands in Scottish lochs which have to-day every appearance of being natural have turned out on better investigation to be wholly artificial, or true crannogs.

In this north-eastern district crannogs are necessarily scarce since lochs are few, except among the mountains; but one, or possibly two, are still existent, and another is on record. The last, in the Loch of Leys, Banchory in Kincardineshire, was examined when the loch was turned into dry land in the middle of last century. It measured about 65 yards in length and 30 in breadth. Kitchen vessels of bronze, a mill stone, antlers and bones of a red deer of great size, a small canoe of oak, and a boat about 9 ft. long were found. The other crannog site is Loch Kinnord. Two islands can be seen there, the larger one being about 100 yards in length by 70 in breadth and the smaller 25 yards in diameter. The latter is certainly wholly artificial, being formed of an arrangement of piles, beams and stones. The larger island has not been definitely ascertained to have been originally a crannog, but certain significant facts could be mentioned connected with it which indicate that it was so. Three canoes were recovered from the bottom of the loch at various times during last century, while a fourth is still submerged near the smaller island. They are formed out of single logs of oak, and are 22, 29 and 30 ft. long. The breadth of the larger two is about 3 ft. A bronze jug, 10½ in. high, with handle and spout, and similar to the one from Loch of Leys crannog, was found, and also a bronze spear-head, with a portion of the oak shaft remaining in the socket, 12½ in. long, which is in the University Museum.

Hill forts.—The essential features of such early places of defence are their situation on the top of a hill, and the presence of a space, varying in size, enclosed by a circular rampart made of stone or by a concentric series of ramparts, with intervening trenches. In those called vitrified hill forts, parts of the stone walls show evidence of the action of fire, but the process by which vitrification was achieved is not altogether understood.

Many examples of these exist in the district, and particular mention may be made of a few as specially worthy of attention. The sites are: the hill of Bennachie, Barrahill not far off, the Barmekin of Echt, the Tap o' Noth, Dunnydeer near Insch (with remains of a later medieval castle in the interior), the last two being vitrified.

Chronologically these forts belong to the same period as earth houses and crannogs.

XI.

AGRICULTURE IN THE NORTH-EAST

BY

J. F. TOCHER, D.Sc., F.I.C.

GENERAL REVIEW.—Aberdeen occupies a unique position among the counties of Scotland from the point of view of agriculture. The county has the highest acreage under cultivation of all Scottish counties, and also the highest acreage in each of the following crops, namely : oats, turnips and rotational grasses. It has the greatest number of horses, cattle and pigs of any county in Scotland. Of the total 621,000 acres in use for agricultural purposes 49 per cent. is in rotational grass, 29 per cent. in corn crops (oats, 28 per cent.), 12 per cent. in turnips, $8\frac{1}{4}$ per cent. in permanent grass, $1\frac{1}{4}$ per cent. in potatoes and $\frac{1}{2}$ per cent. in other crops. It is also the county of small holdings. Over 58 per cent. are holdings of 50 acres and less. Only 1·4 per cent. are over 300 acres. The following table shows the number of tenants with holdings of various sizes.

Table

Acres Above	Acres Under	Number of tenants	Tenants per cent.
1	15	3,543	34·61
15	50	2,435	23·79
50	100	2,245	21·93
100	150	1,004	9·81
150	300	867	8·46
300		143	1·40
		10,237	100·00

Aberdeenshire has 570,000 acres arable land, of which 170,000 are in oats, 75,000 in turnips, and 300,600 in rotational grass. Perth is second in oats with 58,000 acres, and Angus second in turnips with 28,000 acres. The latest available figures show over 23,600 horses and over 173,000 head of cattle in the county of Aberdeen, or 16 and 14 per cent., respectively, of the numbers for Scotland. Although there are over 400,000 sheep in the county, Aberdeen occupies only the sixth place as a sheep county. Feeding and breeding are characteristic of Aberdeenshire. Turnips, straw and ensilage (augmented where necessary by concentrated feeding stuffs such as linseed and cotton cake) are used for feeding and preparing cattle for the market. Over a million tons of turnips are produced and

consumed annually by the live stock of the county. Oats and turnips are grown for live stock. Hay and oats are the principal feeding stuffs for horses. The 8,000 farmers with holdings of 100 acres and under do most of the work of the farm themselves. Those ' eident ' hard-working men are the backbone of the county.

There are 620 registered dairy farmers in Aberdeenshire owning about 10,800 cows. During 1933 the Milk Agency, voluntarily organised prior to the 1931 Marketing Act, handled $5\frac{1}{2}$ million gallons, of which $1\frac{3}{4}$ million gallons were surplus to the liquid needs of the city of Aberdeen. In order to encourage an increase in the consumption of milk an advertising scheme was started by the Agency and others. The result of this scheme was very satisfactory. There was an increase in consumption to the extent of over 200,000 gallons when compared with the previous year. This is an encouragement to the scheme of advertising throughout the whole country. Since milk is of primary importance to the health of infants and the young generally an increase in the consumption of liquid milk in the North-east would contribute to an increase in the health of the community.

The Beginnings of Intensive Cultivation.—The particular type of cultivation and its intensive character arose through the efforts of men like Sir Archibald Grant of Monymusk, Udny of Udny, Barclay of Ury, and the Earl of Erroll. These landowners and others encouraged thorough cultivation of the soil. They brought from the south farm hands familiar with the new methods to educate their tenants in the new methods. Land was reclaimed first by the landowner and then by the farmer. Grasses were sown and turnips introduced throughout the whole of the North-east.

The writer had the privilege, in 1889, of recording the efforts of several generations of Aberdeenshire farmers in reclaiming land for cultivation, efforts which are typical of the industry of the whole of the north-eastern farming community as the result of Jethro Tull's book, which appeared just two hundred years ago.

The Making of an Aberdeenshire Holding.—The farm in question, Atherb, Maud, was reclaimed by John Milne's ancestors from 1783 onwards. At the end of the eighteenth century the rent paid for 56 acres was £5, of which 20 acres were reclaimed, the remainder being heather, broom and whins. Little produce was sold off the croft. The chief source of revenue was the money earned by the women spinning lint. The only kind of purchased manure which was applied to the land was limestone. By 1841 the rent was £25. Economy had to be severely practised. Tea was indulged in only on Sunday morning. Tobacco was a luxury not to be thought of. When oatmeal got scarce before harvest, the household had to fall back on potatoes. Phosphates in the shape of crushed bones was first applied to the land in 1838. Guano was applied for oats on new land in 1846 and proved a great boon to the tenant. In 1856, a threshing mill—a great factor in the making of Aberdeenshire tenant farmers—was installed in Atherb. The total rent paid from 1783 to 1878 was £1,640. The landowner paid only £16 on repairs during that period. And all the time the land was reclaimed, and

the soil improved by the application of manures, the total sum expended from 1885 to 1899 being £1,444. This is one example among thousands of tenant farmers 'tyauvin'' to make a livelihood, morning, noon and even night. Of such stuff is the north-eastern farmer made.

EARLY RECORDING.—A sidelight on the interest in records taken by farmers in the North-east was recently provided by Dr. C. W. Sleigh in a paper [1] in which he gave extracts from a journal written between 1793 and 1797. This journal contained barometric and thermometric records and records of the names and the work of farm hands, the rate of pay, the horses and oxen employed, the hoeing of turnips, pulling and threshing lint, live stock and grain disposed of and many other details, including the most important of all entries, namely, money received and money paid. A farmers' club existed in Aberdeenshire in 1758. Papers were read by its members giving the results of experiments. This club was therefore the precursor of the North of Scotland College of Agriculture, which was instituted in 1904.

THE NORTH OF SCOTLAND COLLEGE OF AGRICULTURE.—The first provision for Agricultural Instruction in the North of Scotland was a bequest in 1790 by Sir William Fordyce for lectures in chemistry, natural history and agriculture at Marischal College. The bequest became effective in 1840 after the expiry of a life-rent, and thereafter a course of twelve lectures was delivered each year. In 1892 the Fordyce Foundation was merged with other university trusts, and the University of Aberdeen became responsible for the lectures.

To provide for further development, the North of Scotland College of Agriculture was established in 1904 and became responsible for the Agricultural Department in Marischal College, one of the colleges of the University of Aberdeen.

The former lecturers, who were under the Joint Committee and were taken over by the College, were Mr. R. B. Greig (now Sir Robert Greig, late Secretary of the Department of Agriculture for Scotland), Fordyce Lecturer; Mr. James Hendrick (now Professor of Agriculture in the University), Lecturer in Agricultural Chemistry; the late Mr. J. M. Young, Lecturer in Veterinary Hygiene; and the late Prof. J. W. H. Trail, Lecturer in Agricultural Botany and Agricultural Zoology. At the present time, the staff of the College has increased to a total of sixty-three full-time officials, including organisers and instructresses resident in all the counties of the North of Scotland. There are in addition a number of part-time lecturers.

The nett expenditure of the College in its first year amounted to about £5,000. It now stands at about £28,000.

In 1911 arrangements were made for the purchase of the estate of Craibstone, situated about five miles from Aberdeen, in order to establish an experimental farm which is largely taken advantage of by the farming community. In addition to the College Farm, a School of Rural Domestic Economy, opened in 1923, is accommodated on the estate, while there is also a large forest demonstration area where a great variety of trees has been planted.

[1] *Transactions of the Buchan Field Club*, 1931, vol. xiv, pp. 63–77.

THE ROWETT RESEARCH INSTITUTE.—The scheme for the promotion of scientific research, adopted by the Development Commission in 1912, made provision for the establishment of one or more institutes to carry out research in each of the main branches of agricultural science. The Rowett Research Institute had its origin in this scheme as one of the two institutes for the study of animal nutrition, the other, the senior institute, being established in connection with Cambridge University in 1912. The governing body of the Rowett Institute was constituted in 1913. It consists of ten members, four appointed by the Court of Aberdeen University, four by the North of Scotland College of Agriculture, and two jointly by both bodies. Work was begun in April 1914, the use of laboratories and other accommodation being granted by the University and the College of Agriculture until the buildings required for the Institute could be erected. Dr. J. B. Orr was appointed in 1914 to take charge of the work on animal nutrition, while joint work with the College of Agriculture and the University was also undertaken on soils and draining and Isle of Wight Bee Disease under the supervision of Prof. James Hendrick and Dr. John Rennie respectively. On the outbreak of war, the main research work and the arrangements being made for the development of the Institute were suspended, the subsidiary work on soils and bee diseases being carried out by the College of Agriculture and the University on a modified scale. After work had been resumed in 1919 in a building erected for the purpose on the Craibstone estate belonging to the College of Agriculture, proposals were submitted by the governing body to the Development Commission for the further development of the Institute. The proposals included the provision of (1) central buildings with laboratories, animal houses, and other accommodation required for research in animal nutrition; (2) an experimental stock farm; (3) a library and a statistical department.

In 1920 Mr. John Quiller Rowett provided money to purchase 41 acres of land on which there was a suitable site for the central buildings, and gave in addition £10,000 for capital expenditure. The building was begun in February 1921, and opened by H.M. Queen Mary on September 12, 1922.

As soon as the scientific research work of the Institute had been organised arrangements were made for the development of the experimental stock farm. In 1922 a croft was leased and the buildings altered for animal experiments. In 1925 Mr. J. Duthie Webster made a gift of £10,000 (afterwards increased to £12,000) for the purpose of establishing the Duthie Experimental Stock Farm as a memorial to his uncle, the late William Duthie of Collynie. The farm extends to about 600 acres, with hill pasture in addition, and has departments for dairy cows, beef cattle, sheep, pigs and poultry. The east wing of the first floor of the central buildings was planned for a library and a part of the annual income of the Institute was devoted to the purchase of books and journals. In 1923 Mr. Walter A. Reid, C.A., LL.D., gifted £5,000 to endow the library. Grants were also received from the Carnegie Trust and the Department of Agriculture for Scotland for books and equipment, and the library and statistical department were established. Arising from

the Imperial Agricultural Conference in 1927 the Imperial Bureau of Animal Nutrition was established within the Reid Library in 1929. It is a clearing house for information and links together the work on animal nutrition which is going on in various laboratories and experimental farms throughout the Empire. It provides opportunities for exchange of ideas, for comparison and correlation of results, and for personal contacts between workers at home and abroad. In 1931 there was issued from the Reid Library the first number of the journal *Nutrition Abstracts and Reviews*. This journal is published quarterly and is issued under the joint direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library. In addition to the journal there have been published from the Reid Library 205 memoirs on the various activities carried out at the Institute. A number of books on other subjects of general interest have also been issued. In 1932 Strathcona House was opened. It is a residence for workers and visitors to the Institute and is the headquarters of a social club open to research workers and others engaged in higher teaching, research and education. The number on the staff of the Institute and Imperial Bureau is about twenty-five, including the heads of the biochemistry, physiology and animal husbandry and the overseas workers and scholars.

THE MACAULAY INSTITUTE FOR SOIL RESEARCH.—The Macaulay Institute for Soil Research, which is situated at Craigiebuckler on the boundary of the city, was established in 1930 through the generosity of Mr. T. B. Macaulay, the President of the Sun Life Assurance Company of Canada, whose ancestors came from the Island of Lewis. The Institute consists of a large mansion house in which laboratories have been fitted up, greenhouses, a large walled experimental garden and nearly 50 acres of land. In addition to the Director (Dr. W. G. Ogg) and the Secretary (Miss Bowman), there are seven members of the technical staff, consisting of a soil geologist, specialists for advisory work among farmers, moorland work, soil surveys and drainage analysis, a technical assistant and a part-time advisory officer who lectures during the winter months. The Institute owns 147 acres of peat land on Arnish Moor, near Stornoway, where field experiments are being conducted to ascertain the best methods of improving peat land. Joint work at the Institute is in progress with the Geological Survey, the Forestry Commission, the Forestry Department of Aberdeen University, the Animal Diseases Research Association, the North of Scotland College of Agriculture and the East of Scotland College of Agriculture.

XII.

AGRICULTURE IN ABERDEENSHIRE IN THE OLDEN DAYS

BY

DUTHIE WEBSTER (COLLYNIE).

In times past in Scotland the roads were fixed by the good fords over the rivers. On this account Aberdeenshire was for long particularly inaccessible. Three rivers cross Aberdeenshire to the sea. The Dee, Don and Ythan isolated the east portion from the south prior to the erection of the ' Brig o' Balgownie ' some 800 years ago. Cattle going south had to ford the Ythan at Tangland, the Don at Thanestane, and the Dee at Kincardine O'Neil, on their way south by the Cairn o' Mount. Droves of cattle went south over these fords from Aikey Fair to the famous Falkirk Tryst. Several thousands in one drove are reported to have passed through Tarves on their way south. These were stirks or cattle to feed, as, until the turnip was introduced about 1750, cattle could not be fattened in Aberdeenshire. Stirks were reared here and went south to England to be fattened. So even the famed roast beef of old England had a little of Scotland in it. Oats were grown in small quantities, a thin crop of poor quality on the in-field, hardly enough to provide meal for the population, not to speak of feed for cattle. What did our forbears do without potatoes or tea ? Potatoes first appeared in some parts of Scotland about the time of the Union. It was then a land of small holdings, held under improving leases which bound the tenant to do everything, build his houses, drain his land, and reclaim all he could from the surrounding heather. His rent was small, mostly in ' kind,' a few hens, some peats, some labour, and a little money. The living was a bare one, the tenants were often on the edge of starvation in winter. The chief articles of food were oatmeal, kail and red cabbage, a little beef and fish. One is not surprised to learn that in these days Scotsmen emigrated in great numbers. There were many small estates, and each had a meal mill where tenants were bound to meal their oats. Oatmeal, the food of the townsman, was the chief article sold by the farmer. After the Bridge of Don was built, meal was carted to Aberdeen from all over the county. While the farmer supplied the meal to the town, his wife washed, carded and spun wool to make worsted for stockings. Stocking merchants traversed the county with a pack selling their goods in exchange for stockings. In the Tarves district a common meeting place was at Raitshill, a small ale-house on the Tarves-Aberdeen road where the wives went with their stockings to meet the merchant, and no doubt got

a little hot ale. A standing joke was that the nearest road to every place was past (bye) Raitshill.

The twelve-oxen plough (the ' twal ousen ploo ') was in common use on the heather land. My grandfather (Wm. Duthie's father) doubled the cultivated acreage of Collynie by reclaiming on his farm. People who could afford it rode on horseback. Most people walked on foot. My grandfather thought nothing of walking into Aberdeen eighteen miles on business and walking back again the same day. He remembered the first gig ever seen in Tarves—a gig owned by Wm. Hay, Shethin. I saw the first motor car.

The original cattle in the North-east seem to have been coloured horned animals in appearance somewhat like the present Highland type. These cattle were improved by crossing of cattle imported from Holland and by crossing with Roman white cattle. England, the more settled country with its fine climate, took the lead. The origin of the hornless (hummel) type of cattle appears to be unknown. In 1827 the introduction of what is now known as the Shorthorn type by Mr. Barclay of Ury did much to improve the cattle of the North-east. Barclay was a Quaker, and the Cruickshanks (of like persuasion) took up Shorthorn breeding at Sittyton, producing a type suitable for our northern climate and conditions. Associated with the name of ' Duthie ' the type is now known all over the world. In recent years a demand for milk has brought the Ayrshire and Friesian prominently into notice. Several herds of these are now in Aberdeenshire, in addition to many herds of dairy Shorthorns. The hen has at last come to her own, and receives now on most farms the attention as to feed and breeding she deserves, with resultant profit to all. The pig just holds his own, that is about all. Sheep, however, have in recent years been the mainstay of the farmer. Pure-bred flocks of all the breeds exist, but the cross-bred is the commonest in Aberdeenshire.

Aberdeenshire has never been a place for light-legged breeds of horses. The heavy horse has always been bred, and despite motor-trackage, a sound heavy lorry horse is still in demand. The mating of live stock is carried on with great skill in the North. Recent scientific investigations on feeding and nurture have added much to our previous knowledge and experience. The treatment and cure of animal diseases has not kept pace with the need, but no doubt that will come in time.

The old-fashioned cheese-press is still in existence, and sometimes used. The up-to-date factory cheese has, however, largely displaced the home-made article. Farm tools have changed but little, except that the self-binder and the oil engine are now universal. The oil-drawn tractor has made its appearance, and efforts to improve the farm cart are now being made. No farmer now keeps a pony. All have motor cars and most farm servants have motor-bicycles. Few farm houses lack a water supply, and most have a hot water circulation and bathroom. Many have electric light, both in the steading and in the house. Wages are high, profits are low, but comforts and conveniences are great. The hardships of our forefathers are forgotten and also, alas, many of their principles.

XIII.

THE SOILS OF THE NORTH-EAST OF SCOTLAND

BY

PROF. JAMES HENDRICK, B.Sc. (Lond.), F.I.C.

THE soils of the North-east of Scotland have been formed almost entirely from debris left behind when the ice melted at the end of the glacial epoch. The whole surface of the country had been planed down by the ice and nearly all the loose material swept away. When the ice melted, it left masses of broken rock of every degree of fineness, and these were sorted out to a certain extent and distributed by the water produced by the melting ice. The underlying rocks from which this debris was derived are generally hard, crystalline, igneous and metamorphic rocks such as granite and crystalline schists. In limited parts of the area there are ancient sedimentary rocks such as the Old Red Sandstone of the Mearns and Moray. The glacial deposits, from which the soils have been formed, are generally closely related to the underlying rocks, and hence in the Old Red Sandstone districts the soils have been largely derived from Old Red Sandstone, while in granite districts the soils are largely derived from granite. In the neighbourhood of Insch, where the underlying rock changes from a basic crystalline rock to slate, a corresponding change is almost immediately found in the soil.

The soils are, generally speaking, very variable in depth and quality. In many places the bare rock smoothed by ice action has been left at or near the surface. In such cases the soils are poor and thin. Poor or worthless soils are also found where the masses of boulders which have been left by the ice form boulder-strewn areas with patches of thin soil. In other areas deeper deposits of finer materials have weathered down to form good fertile soil. Large parts of the area under natural conditions were covered with peat more or less thick. Much of the peat has been removed and the land reclaimed. In other cases where the peaty or moorish layer was thin the land has been reclaimed without removing the peat, consequently there are considerable areas of poor peaty and moorish soil throughout the district.

In all parts of this area the rainfall exceeds the evaporation, so that soluble materials cannot accumulate in the soil; also there is little limestone found in the North-east of Scotland and the soils are almost invariably acid in reaction. The acidity varies greatly from very acid moorish and peaty soils to soils which are only slightly acid, but even on basic rocks, the soils are more or less acid. The more fertile soils are of moderate acidity only, generally about 5·5 to 6·5 *p*H. The principal

crops grown in the district—oats, turnips, potatoes and grass—are those which are suited to soils of moderate acidity. Barley and sugar beet are not so well adapted to the district and can be grown successfully only on soils of low acidity or on those which have been well limed.

It is characteristic of the soils of this area, and especially of those derived from granite and other crystalline rocks, that they contain felspars, mica and other crystalline minerals often in a very fine state of division, which are either unweathered or in a very imperfectly weathered condition. These silicates contain large stores of potash, lime, soda and magnesia, and the presence of these supplies of bases combined in insoluble silicates helps to maintain the fertility and condition of the soil by gradually yielding up bases during weathering, which not only supply food directly to crops, but by neutralising acids prevent the soil becoming more acid than it is. Such soils often contain considerable supplies of phosphate also, derived originally from the presence of apatite in the crystalline rocks from which they have been formed. These soils, formed from crystalline igneous and metamorphic rocks, are often of high natural fertility, especially when well drained, for they contain a good supply of potash, lime and other bases, and are also naturally well supplied with phosphoric acid. As shown below, they are also generally well supplied with humus and nitrogen. Though in many cases they have not been limed for long periods, or have received very little lime, they are not so acid as might be expected. For the same reason, even when they show considerable acidity, applications of lime often produce little effect, for they are already well supplied with lime and other bases in the form of compound silicates which are sufficiently reactive to supply bases for most of the needs of the soil.

As the surface of the country, before it was reclaimed, was largely covered by moorland and peat the soils are generally well supplied with organic matter and contain a fair supply of nitrogen. The minerals forming the soil generally contain iron, often in considerable amount, and the formation of iron pan, due to the solution of iron in the presence of organic matter and its redeposition lower down, where it binds together other materials, is very common. The presence of such a pan from a few inches to a foot or two below the surface often interferes seriously with the fertility and value of the soil by preventing drainage and aeration and by limiting the depth to which plant roots can penetrate. When the pan can be broken up, the fertility of the soil is often considerably improved.

XIV.

THE FISHING INDUSTRY

BY

R. S. CLARK, M.A., D.Sc.

THE fishing industry of Great Britain occupies an important position in the national economy, but only those living in the immediate neighbourhood of the ports or in close proximity to the highways of traffic are able to appreciate the extent of its ramifications, and its vital importance as a source of food supply, as an employer of labour and as a nursery for seamen. This perhaps is not surprising in view of the fact that little more than fifty years have passed since the introduction of the two great factors in modern fishery development—steam power to fishing vessels and the otter trawl as a means of capture. A fish market at any of the great ports on a day of average landings offers a fine opportunity of gaining a first-hand impression of modern fisheries, and British Association visitors are recommended to pay an early morning visit to the fish market of Aberdeen, which is Scotland's premier trawling port. The North-east area possesses also the seasonal herring centres and distinctive ports of Fraserburgh and Peterhead.

Aberdeen Fish Market is a wonderful sight when at 8 A.M. auctioning of the catches begins. The landings are made chiefly by steam trawlers and liners which moor alongside the quay, and here any weekday practically throughout the year there are displayed most of the commercial fish species used as food in this country. Cod and haddock form the mainstay of the landings, while saithe (Black Jacks), whiting, ling, skate, lemon soles, witches, plaice, megrim, halibut, turbot and dabs, as well as other species, are represented. Within recent years, and partly as a result of the seasonal dearth of fish supplies from the nearer fishing grounds, local skippers have mastered the art of trawling for herring, a pelagic fish, and increased landings of this species, the capture of which by trawl was developed by Germany, are being made by our own vessels during the autumn months from the deeper water area of the northern North Sea.

Since the introduction of steam vessels in 1882, and of the otter trawl in 1895, Aberdeen's progress as a fishery centre has been interrupted only by the war, and although the field of operations has had to be extended to keep up the supplies, the total landings in any one year since the beginning of the century have seldom been less in value at the first sale than a million pounds sterling and have actually reached, as in the year 1920, the phenomenal value of three millions.

Whence comes this vast supply of food? The port of Aberdeen is admirably situated geographically as a base for working the productive

fishing grounds of the northern North Sea and adjacent waters, and there are excellent facilities for the disposal and distribution of the catches. It is outwith the scope of this article to discuss the causes of the centralisation of trawling at Aberdeen, but undoubtedly the foresight, ability and enterprise of the early local pioneers played a significant part, as well as the improved methods for fishing in deeper water and on rougher ground which followed the application of steam power to fishing vessels.

Notwithstanding the number of vessels fishing in the North Sea, supplies from this area gradually became inadequate to meet the demand, and by degrees the operations of trawlers and liners radiated outwards from the northern gateways of the North Sea to the Butt of Lewis, to the west coast of Scotland, to Faroe, Iceland and Greenland, to Bear Island, the Barents Sea and the north-western coast of Norway. Foreign vessels working these distant grounds landed large quantities at Aberdeen in the years prior to the war. During the war these operations naturally ceased, but activities were renewed not long after the suspension of hostilities, and in 1925 foreign landings at Aberdeen amounted to more than one million cwts., valued at over half a million pounds sterling. Since that year the foreign landings have greatly declined, and in 1932 they fell below the figure for 1913. The bulk of the landings are made by German trawlers and are effected mainly in the spring months when cod are specially plentiful in Icelandic waters. The German vessels call irregularly at other times of the year, but these visits are now largely for the purpose of landing livers and liver oils extracted on board, for which better prices are apparently obtainable than at their home ports.

A new development in the prosecution of Scottish fisheries took place in 1921 with the introduction of the Danish seine net. This method, adopted by small inshore motor boats as well as by steam and motor drifters between herring fishing seasons, can only be used on smooth ground, but has nevertheless proved so successful as to become an established feature of our national fisheries.

Mention must also be made of the considerable fishery for salmon prosecuted by means of bag and fly nets along the coast, by sweep nets in river tidal waters and by rod and line. For many years the rental value of the Dee fishings has been the highest of any river in Scotland, and in 1932 amounted to £30,797. The fishings on the coast adjacent to Aberdeen and at the mouth of the harbour and the sweep net fishings for a short distance up the river are owned by the Harbour Commissioners, and in the same year a total of 19,940 salmon weighing nearly 1,290 cwts. and valued at £14,038 was sold at the fish market during the netting season which lasts from February to August.

There can be no doubt that the Aberdeen of to-day owes much to the City and Port authorities who in the early years were quick to realise the potentialities of the port as a great fishery centre. Many years before the introduction of steam trawling, improvement of the harbour had been in progress. The North Pier had been constructed and the various quays forming tidal and non-tidal basins had been built or planned. The river Dee had been diverted and its channel widened and deepened, thus enabling a large tract of land to be reclaimed and occupied later by

streets, and by offices, factories and yards connected with the fishing industry. The building of Victoria Bridge made available a large and conveniently situated area south of the river soon to be utilised for more commercial buildings as well as for houses for the growing population. Until the eighties of last century a small fish market existed at the foot of Market Street, but because of its inconvenient situation and inadequate size this soon had to be abandoned. Though the landing wharf and market on the north side of the Albert Dock—a tidal basin, 22·9 acres in area—were not ready for use until 1889, events have proved that the time spent in careful planning and carrying out the extensive works these plans entailed was well worth while. The regular use by the Harbour Commissioners of modern dredging plant to remove the silt, sand and shingle deposited in the navigation channel by sea and river has enabled fishing vessels to enter or leave the Albert Basin at practically any state of the tide. Compared with the fish market to-day the building opened in 1889 was small, being only 500 ft. long and 40 ft. in width. It was so situated, however, that extension was a comparatively simple matter, and from time to time, as the needs of the industry for more market space became clamant, additions and improvements have been made. The present market, occupying an area of 16,119 square yards, is nearly half a mile in length, with a breadth for the greater part of 52 ft., and almost fulfils the dream of one early noted pioneer who ' trusted that he might live to see the market right round the Albert Basin.' The market floor is 2 to 3 ft. above street level, while wide doorways on the street frontages facilitate the rapid transference of the fish to the processing yards and factories. An abundant supply of water and a large staff of men, employees of the town, ensure the thorough cleansing each day of the extensive concrete floor. The provision of the new market, the steadily increasing landings and the method adopted of auctioning the catches resulted in an influx of buyers who, as a class, have never ceased to seek and utilise new and more efficient ways of treating and marketing the prime products of the sea. Village methods of curing were first adopted, and rapid improvements in technique soon made Aberdeen ' finnans,' ' pales ' and ' smokies ' renowned and appreciated in all parts of the world. The most noteworthy advance in recent years, and one which has done much to popularise fish as a table delicacy, has been the development of filleting, which has provided the consumer with a boneless product either in the fresh or cured condition. The opening up of the Iceland grounds principally by German trawlers provided ample material for a great export business in hard dried, salted cod and saithe, and raised Aberdeen to the position of Britain's leading centre for this trade.

Space permits of only brief mention of the many subsidiary industries brought into existence. The local manufacture of great quantities of ice, about 120,000 tons annually, for the preservation of the catches, the shipping and handling of coal, shipbuilding, engineering and repairing establishments, including three pontoon docks, the growing use of motor transport, box and barrel making, the manufacture of bye-products—fish meals, fertilisers, glue, and fish liver oils of proved medicinal value—and the packaging and daily despatch of the processed fish by rail and road

to the densely populated areas in the south, all provide employment for thousands of men and women.

Since the war the industry has been faced with tremendous difficulties, chiefly on account of the high cost of production, the relatively lower price of fish and the loss of foreign markets, but owners and fishermen with characteristic fortitude and tenacity have stemmed the tide and there are signs that the industry is slowly but surely regaining its former prosperity. The introduction of the seine net and improvements in the otter trawl have added to the supplies, while new engineering developments have helped to reduce the running costs. Experiments on better handling of the fish at sea and more scientific methods of preservation have resulted in improved quality of fish and higher prices. Attempts are being made at sea to utilise the waste products and to render oils from the fresh livers in a raw state for further refinery ashore.

On the shore side of the industry progress has kept pace with the changes occurring in the character of the material. The intensity with which fishing has been prosecuted and the relative scarcity of large sizes have resulted in fish of small size, principally haddock, being brought to market in much greater quantities than in earlier years. This development presented the fishery scientist and administrator as well as the fish merchant with difficult problems, but the introduction of 'block-filleting' has enabled the latter to utilise these small fish and to offer the consumer a cheap, attractive and wholesome food. The use of machinery in the preparation of both white fish and herring is still in its infancy and is likely to extend greatly in the future. Motor transport is receiving greater attention and advertising of fishery products has greatly increased, much to the benefit of the industry. Aberdeen is not lagging behind in any of these activities.

Aberdeen is no longer an active herring fishing centre, but on account of the importance of this branch of the industry to the North-east of Scotland and the town's connection with it, some reference to this section will not be inappropriate. In the early days when the Government endeavoured to encourage the herring fishery by means of a bounty the boats at the two creeks, Footdee and Torry, were too small to participate in the fishery. Not until the seventies, when the herring curing industry was in a prosperous condition, did the Aberdeen fleet begin to increase steadily, and in the early eighties the port had become one of the important herring fishing centres. While the great bulk of the catch was cured for the Continental markets, considerable quantities were sold fresh, converted into kippers, or preserved in tins for export. Decline set in with the appearance in 1899 of the steam drifter, which brought grounds at a considerable distance from Fraserburgh and Peterhead within the daily range of the fleets fishing from these ports. It became unnecessary, therefore, and uneconomic to transport curing stock and personnel to the more southerly ports in the vicinity of which shoals are later in appearing. At the same time the growth of Aberdeen as a trawling centre resulted in competition for berthing and curing facilities, and the seasonal drift-net fishery had little chance of survival.

The history of the counties of Aberdeen and Banff in their relation to

the origin and development of the herring fishing may not include such stirring events as are associated with the period when Holland and Great Britain were contending for supremacy in the same field, but since the system of Government bounties ended, progress in marketing has kept pace with new developments in the means of capture of this pelagic species, which has been and is of such importance to Scotland.

The vessels employed under the Government bounty system were of considerable size and capacity, but those owned subsequently at the northern ports confined their operations to their own shores and did not exceed 33 to 40 ft. in length. Their range at sea was consequently a limited one and the outlet for their catch was of a very circumscribed character. With the gradual expansion of markets on the Continent of Europe, however, demand was gradually stimulated, and the price obtainable improved.

Coincident with the upward trend of demand there was corresponding pressure for the extension of catching power, which was met by the building of larger boats with extended sea scope. This continued until sailing boats 65 ft. long, with ample sea range and capable of landing large quantities of herring, were quite common.

The next change was that inaugurated by the advent of the steam drifter, and it exercised a profound influence upon the fortunes of the industry. The catching power, speed and range of the fleet were so materially augmented that herrings caught within a radius of 100 miles of a port might be landed daily. In the development accompanying the employment of these vessels the counties of Aberdeen and Banff occupied a prominent place.

Meantime a further change is engaging the attention of those interested in the type of motive power and craft best adapted for the economic capture of herrings. Already vessels fitted with the Diesel engine are in service, and the results of their operations clearly establish a balance in their favour in respect of running costs. Against this, the protagonists of steam maintain that the life of the Diesel craft cannot possibly be more than half that of a steamer, and that superiority of the steam drifter in contending with adverse weather conditions is also an important factor in its favour.

The nets used for the capture of herrings have shared in the general advance by periodic adaptation to the needs of the industry. Cotton has replaced hemp as the material from which nets are fashioned, and the stretch of nets now put in the water by the fleet of drifters has multiplied the catching power enormously. The length of net in use to-day is 55 yards, while the depth is about 15 yards, and anything up to 100 nets are shot at one time.

The application of steam to the propulsion of the vessels was accompanied by equally effective improvements in the equipment for handling gear and discharging the catch, and all contributed to increased catches and quicker landings.

Only very small proportions of the herrings landed at Scottish ports are consumed in this country in the fresh state or in the form of kippers. Unfortunately for the industry, especially at the present time, pickled

herrings do not appeal to British taste and the greater part of the catches, pickled and packed in barrels, is exported. In the last decade of the nineteenth century Scotland's production of cured herrings ranged between 900,000 and 1,000,000 barrels, to which total the counties of Aberdeen and Banff contributed no less than half, Fraserburgh being the predominant producer, with Peterhead a good second. In 1913 the total cure in Scotland was 1,285,000 barrels, but the trade has passed through severe vicissitudes since the war and in 1932 the cure fell to 560,000 barrels. With the passing of the wave of economic depression which has so greatly affected trade generally, the industry will no doubt recover much of the lost ground.

An account of the fisheries of Aberdeen and district would be incomplete without some reference to the two Government fishery research institutions. The senior of these is the Laboratory of the Fishery Board for Scotland, situated in Wood Street, Torry, which is the headquarters of sea-fishery research for Scotland. The staff at that station is concerned with research into fish up to the time when they are caught, and from that point the story is taken up by the research station of the Department of Scientific and Industrial Research, also situated at Torry, which deals with problems of preservation and subsequent treatment of the fish.

The writer wishes to express his thanks to those who so willingly assisted in the preparation of this article and particularly to Mr. George Hall and Mr. Eric Wilson for the active part taken in its compilation.

XV.

PAPER-MAKING IN ABERDEEN AND DISTRICT

BY

JAMES CRUICKSHANK.

General.—Paper-making has for long been one of the most important industries associated with the district round Aberdeen, but because of the comparatively wide distances that separate the various factories, this importance is not often realised by visitors, and is apt to be overlooked by Aberdonians themselves.

One learns from old almanacs that a paper mill existed near the city as far back as 1696, but it is not till the middle of the following century that sure ground is entered upon, since which time the industry has been marked by steady progress and continuous growth. Some mills have meantime passed out, but others have arisen to take their place,

and to-day the manufacture stands at a higher level than at any previous time in local history.

At first sight it may appear singular that paper-making should have taken root and flourished in the North of Scotland, so far from the leading centres of consumption. This was largely due to the introduction of machinery in place of the slower hand-made process, which resulted in supplies far in excess of local demand and led manufacturers to seek new outlets, at first in the home market and gradually by export to other countries. A ready means of transit was found in the trading vessels which sailed from Aberdeen to many quarters, and the coming of steamers and railways did much to improve these facilities. Another important factor was that bulky raw materials could similarly be brought in at low rates. With advantages like these it was possible to land paper from Aberdeen at leading ports such as London at lower freight charges than were obtainable at many inland centres of the industry.

Then again Aberdeen is finely served by its two rivers, the Dee and Don, and their lower tributaries, which afford an ample supply of water specially suited for paper-making, and provide, at the same time, a certain amount of power.

Lastly, there being few other outlets for employment near the various mills, a type of skilled worker began to arise, as fathers were followed by their sons, with the result that excellence in quality early became a noted feature of Aberdeen paper.

It should also be emphasised that, while the mill-owners have all along shown enterprise in searching out new processes, they have, at the same time, displayed much spirit in handling and developing trade, as may be gathered from the following short review of the various works, which number five in all.

Culter Mills—Culter Mills Paper Co., Ltd.—The Culter Mills, which are situated about eight miles from Aberdeen on the Culter Burn and near the river Dee, were founded in 1750. They deserve priority of place because they were the first of the local group to be formed, and also because they were the first to set up a paper-making machine, known as a Fourdrinier, from the name of the firm which first introduced machinery for the making of paper.

An advertisement early in 1751 makes clear that the founder was 'Bartholomew Smith, Paper-maker from England (a native of Middlesex), who has set agoing on the Burn of Culter a Paper-mill where he can serve the country in paper fine and coarse, and gives notice that he buys rags of all kinds of flax and hemp, by the stone weight.' The choice of site was fortunate, for it lies in a sheltered position amid attractive surroundings, while a plentiful supply of pure water is obtainable from the Culter Burn, which has its main source in the natural reservoir of the Loch of Skene. At his death, some seven years later, we learn that he had built up an improving business, to which his son Richard succeeded, who was to hold the reins for the long period till 1803.

A local historian writing about 1790 has placed on record that about this period superfine paper and paper for notes to the Aberdeen Bank were amongst the articles being produced, and that the writer had himself

used the fine post paper, made by the mill, which was equal in quality to any he had ever seen. It is elsewhere stated that the mill made use of the whitest of rags which required no bleaching. Lewis Smith succeeded to the business on the death of his father Richard, and, amid the difficulties of the times, carried it on till his death in 1819, when the long family connection ceased. For the next half-century there were various changes of ownership, with, however, no backward tendency, till in 1865 the Culter Mills Paper Company, Limited, was formed. In the intervening years the mill has been completely remodelled, and the number of modern making machines now stands at four, while a large coating plant has been installed, besides other new departments.

Esparto writings, together with rag and wood-pulp papers, are the leading productions in a wide variety of types, and, in addition to an extensive home trade, a large export connection has been built up.

During a period of over half a century the leader in these activities and developments has been Mr. J. L. Geddes, with whom for a number of years have been associated his sons, Mr. J. Fraser Geddes and Colonel G. P. Geddes, D.S.O.

Stoneywood Works—Alex. Pirie & Sons, Ltd.—Stoneywood Works were founded in 1770 under the following circumstances: James Moir of Stoneywood had taken a prominent part in the rebellion of 1745, and, as a result, had to remain an exile in Sweden for sixteen years. Being at last allowed to return home, he found his estate in great disorder and endeavoured to redeem his affairs by promoting a number of different projects. Not many of these succeeded, but one was to have a far-reaching influence, viz. the lease by him of an island on the Don for setting up a paper mill. The lease was to John Boyle, bookseller, and Richard Hyde, dyer; but within three years both had sold their shares to Alexander Smith, a chirurgeon-barber in Aberdeen. The daughter of this Alexander Smith married Patrick Pirie, merchant in Aberdeen, and through this union the connection of the Pirie family with paper-making was begun, a connection that is to-day maintained by members of the fifth generation of Piries.

For the first quarter of a century the mill was only of moderate size, as an inventory made in 1796 shows that there were two vats; the stock was some 500 reams of paper (all of the coarser grade), the raw materials 20 tons, the value of the whole £500, and the number of employees 16; while the clientèle was purely a local one. About the year 1800, shortly after Mr. Alexander Pirie had succeeded, the white paper trade was taken up, which marks the beginning of the now famous 'Pirie' water-mark, examples of that time being still preserved. The hand-made process continued in use till 1822, when Mr. Pirie laid down his first paper-making machine; but he had the misfortune to see the mill almost swept away and the machinery badly damaged in the historic flood of 1829. Nothing daunted, he restored the buildings and installed two machines, mostly for Writings and Printings. In 1848 large extensions took place, and in the main building the disused belfry of old Marischal College was erected, where it still remains.

About 1856 the firm bought the neighbouring print mills at Woodside,

which were thenceforth used for the preparation of rags. About the same time, Union Works, Aberdeen, were acquired for the making of envelopes. Both works are still being used for these respective purposes.

Meantime the main works at Stoneywood continued to grow, and almost each decade saw the installation of an additional machine. The discovery of the paper potentialities of esparto grass and, later, the introduction of wood-pulp gave new impetus to the output, although rags continued to be the main basis in the extensive range of qualities.

Messrs. Pirie were not slow to recognise the value of International Exhibitions, and they gained medals at Paris, Philadelphia, Sydney, Melbourne, etc.

The number of making machines in operation to-day is eight, enabling the mill to rank as one of the largest in the kingdom. The qualities manufactured consist of tub-sized rag papers, esparto grass and wood-pulp papers, coated papers and numerous specialties.

In 1922 the Company was affiliated with that of Messrs. Wiggins, Teape & Co., Ltd., and it is now one of the leading partners in the large combine which has since been established. Captain J. S. Allan, F.I.C., Director of Alex. Pirie & Sons, Ltd., and Wiggins, Teape & Co., is in charge of the works.

Mugiemoss Works—C. Davidson & Sons, Ltd.—The founder of Mugiemoss Works was Mr. Charles Davidson, and the business has since been carried on by his descendants, down to the fifth generation. Early in life his connection with paper-making began, as partner in 1796 of a mill about two miles higher up the river Don; but, after a number of years, he branched off on his own account, and finally established his paper mill at Mugiemoss in 1821. The site offered a good many advantages, as about this point the river makes a considerable fall, and the Bucks burn joins the river near by.

For the first few years he confined himself to papers made by hand, but in 1827 he decided to erect a machine of his own devising, after the type of the 'Fourdrinier,' and thereafter the production increased rapidly. But two years later he was to share in the disastrous flood that had affected so many of his neighbours, the buildings were destroyed and the stock carried away. He set himself without hesitation to retrieve the loss and in a short time was at work again on a larger scale than before.

After the death of Mr. Davidson, his sons, who in 1831 had been assumed as partners, continued the work of their father, and in 1844 erected a second machine. They too suffered misfortune, this time by a fire in 1854 which destroyed a large part of the mill, but it was soon rebuilt and continued to grow.

The Mugiemoss Mills to-day concentrate on kraft and sulphite wrapping papers, and they specialise in cedar felt, roofing felt and creped papers. They also devote much attention to the making of paper bags.

There are three making machines in operation and there are also extensive printing and lithographic works.

The present Managing Director is Colonel T. Davidson, D.S.O., with whom is now joined his son, Mr. D. P. Davidson.

Inverurie Mills—Thomas Tait & Sons, Ltd.—Inverurie Mills are situated on the river Don, about fourteen miles from Aberdeen, and were established in 1860 by Mr. Thomas Tait, whose descendants to the fourth generation are still in control.

They occupy a suitable position near the river, and not far from the intake of the former Aberdeenshire Canal. The canal was closed in 1853 to make way for the railway which was opened in the following year, and the uppermost section of the disused waterway came in conveniently as a medium for providing driving power to the new paper mill.

The possibilities of esparto grass, grown in Spain and North Africa, came under the notice of paper-makers about this time, and this was doubtless one of the inducements to laying down the mill at Inverurie. At any rate, it was with esparto grass that the mill started off, being the first mill in the North to use it, and this has continued to be the material by which the mill has mainly stood. An interesting reminder of these early days is preserved at the works in the shape of a primitive boiler for treating the grass.

When the mill started off the excise duty on paper was still operative (£14 14*s*. per ton), and it is of interest to observe in the works a document, dated April 23, 1860, licensing the firm to make paper, subject to the payment of the usual duty—a burden that was removed from the industry in the year following.

In 1886 the firm laid down an additional machine to the one already in use, and installed a plant for manufacturing wood-pulp from the log by the sulphite process, and although this was an untried venture in the North, it continued to be highly successful. In 1910 this process was brought under the Chemical Acts, requiring the payment of special taxes, and it then became possible to bring in wood-pulp from abroad on a cheaper basis. Consequently this branch of the firm's works had to be discontinued in 1915.

As already indicated, the product of the mills is essentially finest esparto papers, specially those suitable for typewriting and duplicating. The firm export a considerable proportion of this output.

The Managing Director is Mr. Thomas Tait, assisted by his son, Mr. William Tait, C.A., and Mr. J. Leslie Tait is Secretary.

Donside Mills—Donside Paper Company, Ltd.—Donside Mills occupy a position two miles up the river Don, approximately on the site of the early mill which, as already stated, was in existence in 1696. In 1888 Mr. John Shand resumed paper-making by converting a meal mill for the manufacture of brown wrappings, and he was followed in 1893 by Messrs. John Leng & Co., Dundee, who changed the name from Gordon's Mills to its present designation.

The Donside Company is thus the youngest member of the local group of paper mills, but in the past forty years it has amply justified its existence. For situation it is specially favoured, lying as it does on low ground by the river amid striking scenery. Near at hand are the cruives or dykes, below which, on the morning when the spring salmon fishing opens, hundreds of fish are caught by nets between midnight and dawn, while in the immediate foreground are two of the most noted

historical sights of Aberdeen, the Brig o' Balgownie and St. Machar's Cathedral.

The class of paper manufactured in the two huge fast-running machines is chiefly newsprint, of which the mill is the largest producer in Scotland. The Company is now incorporated in the Inveresk group of mills.

A leading figure in the history of the Company has been Sir Frederick E. R. Becker, whose son-in-law, Major W. G. Moore, is now in charge of the mill.

Statistics.—To conclude this survey of paper-making in Aberdeen, the significance of the place it holds may be inferred from the following figures, which, however, are merely a rough estimate :

Capital employed	£2,000,000
Number of machines	20
Annual output	60,000 tons
Value of output per annum	£2,000,000
Persons employed	3,500
Wages, etc., disbursed per annum	£400,000

XVI.

ABERDEEN GRANITE INDUSTRY

BY

W. D. ESSLEMONT, M.A., B.L.

One of the most important industries of the City and County of Aberdeen is the quarrying and manipulation of granite. An inexhaustible supply of granite of unsurpassed durability and beauty forms the chief source of mineral wealth of the district.

Many quarries have from time to time been worked in the district. In the vicinity of the city the principal quarries at present in operation include Rubislaw, Sclattie and Persley, which yield a grey stone. Peterhead granite, quarried in the immediate neighbourhood of that town, is mostly of a red colour. In the upper reaches of the Don are situated Kemnay, Tom's Forest and Corennie quarries ; the typical colour of their granites is grey, with the exception of the Corennie stone, which is mostly pink. Rubislaw and Kemnay quarries are the two largest in the United Kingdom.

Aberdeenshire granite has been used for building material for more than 300 years, the blocks strewn about the surface being utilised for this purpose in the earlier days, but quarrying in the modern sense was not begun till the middle of the eighteenth century, and it was a long time before methods were devised to secure a plentiful supply of stone.

As long ago as 1764 the characteristic qualities of Aberdeen granite attracted the attention of engineers and surveyors and it was specified by the contractors for paving the streets of London. We learn from Kennedy's *Annals of Aberdeen*, published in 1818, that quarrying operations for this purpose were commenced on 'the rocks on the sea coast of the lands of Torrie' and the stones were transported to London. A stone trade, for supplying the demands of London, was thus established in Aberdeen and carried on for many years and was 'productive of advantage not only to the town and the county, but to the shipping belonging to the port. The landed proprietors availed themselves of the demand for stones, and got rents for their quarries far beyond their utmost expectations. But independent of this circumstance, these undertakings employed a number of poor labourers, and brought many people from the north, who found constant work at these quarries.' Between 1780 and 1790 as many as 600 men were employed in the Aberdeen quarries. For the year ending July 1, 1821, the quantity of granite stones exported was 41,000 tons, the value of which was upwards of £40,000.

From an agricultural survey of Aberdeenshire by Dr. James Anderson, published in 1794, containing a valuable chapter on the minerals of the county, one gathers that the pick and wedge were then the principal tools used in quarrying. For ordinary mason work the stones were used with very little dressing, but for the fronts of houses and finer works they were usually smoothed so as to form what is called ashlar work. There are still several old buildings and erections in the city and neighbourhood, for which all the stones were quarried and dressed by the old-fashioned scabbling pick and the lighter dressing pick: e.g. the nave and west front of St. Machar's Cathedral; the chapel of St. Mary under the East Kirk of St. Nicholas; the granite monument erected by the Town Council in 1637 in a field near Pitmedden to the memory of Mr. Duncan Liddell, an eminent scholar of his day; and Union Bridge, the keystone of which was driven in 1803.

Although, in the early years of the nineteenth century, granite had 'brought gold to Aberdeen,' the tools then used both for quarrying and dressing the stone were similar to those used by the Egyptians three thousand years before.

About 1795 machinery was first employed in quarrying granite. By this means Aberdeen supplied granite in large blocks for constructing the Admiralty docks at Portsmouth and other similar undertakings. For several years the machinery was very crude and little progress was made until the introduction of steam power.

In quarrying Aberdeenshire granite great difficulties had to be overcome. Almost invariably the granite lies beneath a covering of hard boulder clay of varying thickness and rock of an inferior quality, the quality of the stone usually improving with the depth. The removal of the overburden is not only unremunerative but costly. The quarry as it is developed assumes the form of a conical pit with a small floor. The granite is removed by boring and blasting and all quarried materials have to be hoisted to the surface.

The quarrying of granite was revolutionised by the introduction of steam power. The pioneer of the new era was the late Mr. John Fyfe, the lessee of Kemnay quarry. About the year 1870 Mr. Fyfe invented the steam derrick crane. In 1873 he designed and erected at Kemnay the first modern cableway or ' blondin ' in this country. In subsequent years important improvements have been effected in the cableway. The successful commercial working of the Aberdeenshire quarries owing to their great depth and steepness would be impossible at present without cranes and cableways.

The modern mechanical equipment of the quarries has reached a very high standard of efficiency. Pneumatic drills are used for boring the holes necessary for ' plugging ' and splitting the stones. At Rubislaw may be seen the most powerful of quarry ' blondins,' erected in 1928 and capable of raising a weight of 20 tons from the bottom of the quarry, which has a depth of over 350 ft.

The total output of the Aberdeenshire quarries in 1932 was over 402,000 tons.

The uses and purposes which the quarried granite serves are numerous and varied. In the modern quarry practically all waste is eliminated. The best quality of granite is used for monumental and architectural purposes, and the dressing and polishing of stones for these purposes is a separate and special department of the trade. Blocks of somewhat inferior quality are used for ordinary building work. Large stones of great durability are used in engineering and dock works. Medium-sized stones are cut for sills and lintels. Other products are paving setts, rubble stone, road metal and crushed granite. The waste debris of the quarries, when crushed into gravel, makes an excellent surface dressing for walks and garden paths. Great quantities of the waste after being ground into fine powder and mixed with cement are used in the manufacture of adamant blocks for paving.

In Aberdeen and district granite is the material almost universally used for building purposes, probably 75 per cent. of the houses in Aberdeen being built of the grey granite of Rubislaw. Most of the principal public buildings erected in the city within the last sixty or seventy years are built of Kemnay granite. Among the most notable of these are Marischal College, the Post Office and the Northern Assurance Buildings. Persley granite is represented by the War Memorial in Schoolhill and the recently erected building of the Commercial Bank of Scotland.

While Aberdeen granite has been known in the market for upwards of a century and a half as a material for paving, harbour works and building, the specialty for which in later years Aberdeen has become best known is the manufacture of granite for decorative, ornamental and monumental purposes. The origin and early development of this branch of the industry are mainly due to the shrewdness and perseverance of Mr. Alexander Macdonald, who started business in a small way in Aberdeen about 1820. The published accounts of the polished Egyptian granite sent to the British Museum in London by Belzoni, the traveller, directed Mr. Macdonald's attention to the possibility of polishing Aberdeenshire granite. He experimented at the outset on a limited

scale, the work at first being done by hand, and then by a wheel driven by two men. Finally by the use of steam power he was successful in obtaining the results which he desired. He found a ready market for the new product. The first example of a monument in polished granite sent to London from Aberdeen is believed to be one erected in Kensal Green Cemetery in 1832. In 1834 Mr. Macdonald assumed as a partner Mr. William Leslie, the builder of the North Church in King Street, Aberdeen, and later Lord Provost of Aberdeen and Laird of Nethermuir.

When Mr. Macdonald began to polish granite by machinery, other mechanical appliances in the trade were almost unknown. Vast strides have been made since then by the introduction of machinery for sawing, boring and turning of granite and other miscellaneous purposes.

Under the firm of Macdonald & Leslie the business grew and many productions in public and cemetery monuments, architectural and decorative work were turned out. Notable examples of the firm's work are the columns in St. George's Hall, Liverpool; Dunrobin Castle; the two fountains and balustrade in Trafalgar Square, London; the granite statues of the Duke of Gordon in Castle Street, and of Priest Gordon in Constitution Street, Aberdeen, and of Sir Charles James Napier at Portsmouth; the obelisk in Peterhead granite 72 ft. high, mostly polished, erected in Marischal College quadrangle in memory of Sir James McGrigor, Bart., and some years ago removed to the Duthie Park. Fine work was also sent to Australia, India, and other remote parts of the globe. Mr. Leslie retired from the firm in 1853 and the business was carried on by Mr. Macdonald till his death in 1860.

In addition to the business founded by Mr. Macdonald other works of the kind grew up around it. There are at present over fifty firms engaged in this work in the city. Some firms confine themselves almost entirely to monumental work, while the larger firms, in addition to monuments, execute the finer class of building work. In the yards of the latter firms granite is dressed and polished in connection with the erection of important public and private buildings and business premises throughout the country, the fronts of such buildings being frequently constructed of dressed and polished granite of artistic design.

The trade in monumental and architectural work grew to such proportions that the local supply of granite was found to be inadequate to meet the demand. Imports of rough granite from abroad commenced in 1884. Blacks and rich reds from Sweden and Finland and sparkling Labradorites from Norway all in the rough state have since then been imported into Aberdeen, where they are manufactured. These foreign granites afford a greater variety of colour and are in considerable demand in this country. In 1909 as much as 27,308 tons were imported in this way. In 1933 these imports amounted to 15,489 tons. The imported granites are used solely for monumental and architectural purposes.

For some years Aberdeen had a very large export trade in granite memorials. In 1896 America took £55,452 worth of finished stones. Unfortunately the export trade in these monumental stones has seriously declined owing to prohibitive tariffs. The trade with the United States

has dwindled to a negligible quantity, although a fair export trade is still done with Canada.

This branch of the industry has in recent years had to face considerable vicissitudes. Besides the loss of export trade as above mentioned the industry has since the war been faced with foreign competition in the home market. Since 1921 Germany and other foreign countries have exported granite monuments to the United Kingdom in large quantities. Before 1921 there were no foreign imports of the manufactured article. A slight amelioration was granted to the home manufacturer by the imposition of a duty of 15 per cent. in April 1932, and an additional 5 per cent. in June 1934.

Many representatives of the granite industry have taken a prominent part in the public life of the city in the capacity of magistrates, town councillors, and members of other public boards and otherwise. Two of their number have in recent years held the office of Lord Provost of the City, namely, the late Sir James Taggart, K.B.E., LL.D., from 1914 to 1919, and Mr. James Rust, LL.D., from 1929 to 1932.

XVII.

THE TRADE OF ABERDEEN

BY

JOHN S. YULE,

SECRETARY, ABERDEEN CHAMBER OF COMMERCE.

ABERDEEN has been a royal burgh since the time of David I. (A.D. 1080–1153). This early Aberdeen was a purely trading town, and it is significant that the very first royal charter, granted to the burgh by William the Lion (1171–85), is a charter of trade granting to his burgesses of Aberdeen their free hanse (or freedom of mercantile co-operation).

The population of Aberdeen in the reign of William the Lion, although small, as we would now think, was really remarkably large, taking the whole population of Scotland into account. In the thirteenth century the population would be under 2,000, but by the end of the fourteenth century it was, in the matter of population, first among the towns of Scotland. In a notable letter, still extant, sent by Sir William Wallace, the Hero of Scotland, and Sir Andrew Moray, his colleague in the regency, in 1297 to the two chief Hanseatic trading towns Lubeck and Hamburg, it is seen that Scottish traders carried on business all over eastern and western Prussia, and in the old towns of Flanders the itinerant Scottish traders were well known. These traders were also known in Russia and Poland, while in Sweden the activities of the Scottish traders aroused

the keenest hostility among the native merchants. In France, partly through the Franco-Scottish Alliance, which lasted from the reign of John Baliol in 1295 to the Reformation, Scotsmen were everywhere—students, professors in the universities, mercenaries in the French armies and traders in the towns and country districts. As regards the nature of the trade carried on by these merchants, Parson Gordon, writing in 1661, says: 'Many of the citizens of Aberdeen trade in merchandize. The commodityes and staple wair which they carie out for the most pairt are salmond, coarse woolen-cloath called playding, linning cloth, stockines, skins, hydes, and all that the country yields.' The staple fish export from Aberdeen in these days was salmon, and records show that the army of Edward I of England was partly fed on dried fish from Aberdeen, the fish referred to being, it is thought, river fish, salmon and grilse, as no sea fish was then exported; but authorities differ as to this. The earliest information regarding shipbuilding in Aberdeen is of date 1606, when a barque, christened the *Bon-Accord*, was built of timber from the woods of Drum. The Scottish traders of this time had a representative in the Low Countries, Andrew Halyburton of Middleburg, and his business ledger, which is still preserved, shows that among those who exported through Halyburton were various Provosts and well-known business men of Aberdeen, notably Bishop William Elphinstone, who was then engaged in building the new King's College of Aberdeen. Elphinstone's exports consisted of wool, salmon and trout. His imports were carts, wheelbarrows and gunpowder, cloths, spices and comfits for the table. At this time the chief exports consisted of plaiding and woolskins. As regards the inland trade of Aberdeen in the fourteenth century Aberdeen stood actually as the commercial capital of Scotland, and it was not until after 1350 that Edinburgh, now the capital of Scotland, took the first place. In the fifteenth, sixteenth and seventeenth centuries the trade and population of Aberdeen languished, but in the eighteenth and nineteenth centuries there was an amazing recovery, and the middle of the last century may well be classed as the golden days of Aberdeen prosperity, when a large number of important commercial undertakings were founded, such as the Aberdeen, the North and the Town and County Banks, the Northern and Scottish Provincial Insurance Companies, followed later on by the Scottish Employers' Insurance Company. Then the trading companies, the Lime Co., the Commercial Co., the Northern Agricultural Co., and other commercial concerns were founded. At the same time shipping in Aberdeen progressed exceedingly and the Aberdeen clipper became world-famous.

Modern Aberdeen Industries.

Other than Agriculture, Fishing, Granite-working and Paper-making, which are dealt with separately, the following are the main industries:

Box and Barrel Making.—This industry is a comparatively recent one in Aberdeen, but with the growth of the fishing industry, the manufacture of boxes and barrels has grown to a great extent. In Aberdeen there are some of the most progressive and efficient concerns in the country, where one can see the process of manufacture from the round

tree to the finished article. The products of some of the Aberdeen box and barrel factories can be seen from Land's End to John o' Groats.

Cabinet-making and Upholstery.—The cabinet-making and upholstery trade in Aberdeen has always been of considerable importance to the town. Before the days of mass production, practically all the furniture required in the district was made in local workshops, and even with the influx of factory-made goods, there are many people who still prefer the home-made article. The various firms in Aberdeen have always kept themselves up to date, and it is very often remarked by visitors to the city that they see more artistic displays of furniture in Aberdeen shops than in almost any other town.

Recently Messrs. J. & A. Ogilvie, one of the leading manufacturers of upholstery in the city, have made considerable developments in the manufacture of seating and all classes of furnishings for theatres, cinemas, etc., and this promises to be a thriving trade.

The local firms are faced with great competition from mass-production factories from the south, but they seem to be holding their own very well, and the number of cabinet-makers and upholsterers in Aberdeen has remained very steady for a considerable time past. Messrs. Galloway & Sykes, Ltd., another of the leading manufacturers, have added considerably to their factory and warehouse and have also built extensive new premises in Justice Mill Lane, and manufacture all classes of domestic, warehouse and office furniture and furnishings.

Cardboard Boxes.—The cardboard box industry in Aberdeen is perhaps not so well known as it might be. Generally when local box-makers are asked to quote they can more than hold their own with south competition. Besides rigid and fancy boxes manufactured in Aberdeen all manner of collapsible boxes, corrugated containers, as well as cartons and skillets, are now produced by local firms. This has been made possible by the fine spirit shown by numbers of local buyers to purchase locally in order to help and stimulate local trade.

Chemicals and Fertilisers.—Aberdeen being the centre for a large and important agricultural district, superphosphate and other chemical fertilisers are manufactured to a very considerable extent by several firms. Sandilands Chemical Works, belonging to John Miller & Co. (Aberdeen), Ltd., were commenced in 1848, and cover an area of about nine acres. Coal-tar products and sulphate of ammonia are manufactured from the residual products of various gas works in the district, their main source of supply being the Aberdeen Corporation Gas Works. They also make sulphuric acid, as well as superphosphate and other fertilisers. In 1929 this company, together with other large companies manufacturing fertilisers and feeding stuffs all over Scotland, were merged in Scottish Agricultural Industries, Ltd., which is an associated company of Imperial Chemical Industries, Ltd. The other local companies of Scottish Agricultural Industries, Ltd. are John Milne & Co. Ltd., whose works are at Dyce in the neighbourhood of Aberdeen, and who also manufacture sulphuric acid and fertilisers; the Aberdeen Commercial Co., Ltd., a very old-established company who are large manufacturers of fertilisers and feeding stuffs, as well as extensive dealers in grain; and Barclay Ross &

Hutchison, Ltd., agricultural seed growers and dealers and manufacturers of agricultural implements.

Other companies in Aberdeen manufacturing and dealing in all sorts of agricultural products are the Aberdeen Lime Co., Ltd., Northern Agricultural Co., Ltd., and North-Eastern Agricultural Co-operative Society, Ltd.

COMB-MAKING.—For many years Aberdeen has been the centre of the comb-making industry in Great Britain. In fact the works of the Aberdeen Combworks Co., Ltd. are the largest in the world engaged in the manufacture of combs. The works have been in existence for over 100 years, and cover an area of about eight acres, about 300 hands being employed making combs of every description and other articles, including ladies' fancy combs, hair slides, pins, shoehorns, spoons, drinking cups, paper knives, toothpicks, nail cleaners, serviette rings, scoops, spatulas, tobacco boxes, etc., from horn, and from the Company's own non-inflammable substitute, which they call 'Keronyx.' The Company also supply their non-inflammable 'Keronyx' to button-makers and knife-handle manufacturers, and for electrical fittings, this material being an excellent insulator. It is also used for many other purposes.

ENGINEERING.—In recent years the engineering trade in Aberdeen has developed appreciably, making the district a more recognised engineering centre. Several of the best known and more important firms have improved and added greatly to their manufacturing facilities and are in a position to deal with a much larger volume of trade. Local requirements afford a considerable measure of employment in the case of some firms, but the fulfilment of orders coming from other parts of the country, the Dominions, the Colonies and abroad, forms much the larger proportion of the output from most shops. The productions of engineering and shipbuilding firms in Aberdeen and district are of a varied character, among the better known being the following: shipbuilding, particularly for the fishing industry, dredgers and barges, marine engines, marine and land boilers; cranes, conveyors and elevators, aerial cableways and ropeways and all other types of handling machinery; Diesel engines, gas and oil engines, power transmission machinery, air compressors and pneumatic machinery, granite and stone working machinery; coffee manufacturing, rice mill and agricultural machinery; brewing and distillery plant, also castings of iron and non-ferrous metals for all purposes.

FLAX.—At the head of the local textile industries may be placed the flax-spinning industry, carried on at Broadford Works by Messrs. Richards, Ltd. The works have been in existence since 1808, but the present company was formed in 1898. The history of the present company has been marked by great developments in trade and a corresponding expansion of the works. The name of Richards, Ltd. is known the world over and their products have the reputation of which not only the Company itself but also the City of Aberdeen have just cause to be proud. Until 1904 Aberdeen could also boast of having a noted cotton mill in the city. The 'Bannermill' that year, after running for eighty years, had to close down, and about the same time Hadden's Woollen

Mills, in the Green, which had a long history of over a century, also closed its doors. Although by the closing of the Bannermill the cotton industry has been lost to Aberdeen, the closing of Hadden's mills had no such bad result, as the woollen industry has continued to develop in Aberdeen and adjoining shire.

HIDES, SKINS AND TALLOW.—As the centre of a large agricultural district Aberdeen has one or two large concerns dealing in hides, skins and tallow which give employment to a large number of men.

HOSIERY.—The hosiery trade of Scotland began in Aberdeen, with which the African Company (1695) contracted for woollen stockings, and at the time when Pennant wrote (1771), 69,333 dozen pairs of stockings were yearly produced in the city, these being worth about thirty shillings per dozen, and being chiefly exported to Holland for dispersion thence through Germany. Aberdeen is now one of the chief centres in Scotland for the manufacture of hosiery, and over half a dozen firms manufacture hosiery, outerwear, underwear, and knitted woollen gloves. Although, like other branches of industry, they have felt the effect of the trade slump, business is now picking up again, and most of the mills report they are again working full time.

PAINT.—In this particular industry Aberdeen can boast of at least one firm which can claim an unbroken record of more than 100 years. The result of that long period of unabated effort is that paints and enamels manufactured by Messrs. Farquhar & Gill, Ltd., under the good brand of 'Bon-Accord,' are to be found in most of the world's best markets, and to-day there is no brand which can show a reputation for quality superior to that passing under our good city's name of 'Bon-Accord.'

SHIPBUILDING.—Shipbuilding was carried on in Aberdeen as early as the fifteenth century. In the days of the wooden ship the Aberdeen clipper won for itself a wide repute, and after the turn over to iron, steel and steam, the city kept to the front with the construction of passenger and cargo liners and vessels for overseas trade.

To-day, howbeit the big passenger liners and the larger cargo vessels have outgrown the capacity of the port, the three Aberdeen shipyards worthily uphold the tradition of the past for the building of good ships, and examples of their craftsmanship are to be found in all the seven seas. In spite of the adverse conditions shipbuilders everywhere have experienced since about 1921, the trio of local builders have kept the flag flying and secured a fair share of the work available. In addition to vessels for British owners, vessels have been built at Aberdeen in recent years for Australia, New Zealand, South Africa, France, Spain and Belgium.

Opportunity has not been lost during lean times to tighten up and perfect organisations with the determination of being able to compete in all markets open and to secure a full quota of work when demand again arises, as sooner or later it must. Building berths are suitable for vessels up to 350 ft. in length ; high-class passenger and cargo vessels, self-trimming colliers, suction and grab dredgers, coasting vessels, yachts, tugs and barges, are types representative of the production of Aberdeen shipbuilders.

A speciality is made of the building of trawlers, and other types of fishing vessels are also constructed. Of trawlers, the first was built as long ago as 1884, and since then hundreds have been constructed and outfitted, and there are few important fishing ports of the world in which Aberdeen-built trawlers have not operated or in which their reputation for sturdy construction and good sea qualities are not known.

Allied to shipbuilding at Aberdeen is marine engineering, all three firms constructing both engines and boilers for the steam-driven vessels built.

Ship and machinery repairing is also carried on. There are three pontoon docks, the largest 310 ft. long with a lifting power of 5,350 tons, owned by the Harbour Commissioners; also three private slipways suitable for smaller vessels, and the facilities available are thoroughly modern and adequate to the general size of vessel using the port.

As good examples of the recent work of Aberdeen yards in the building of ships may be taken the R.M.S. *St. Sunniva*, a yacht-like passenger vessel, built by Hall, Russell & Co., Ltd., in 1931 for the North of Scotland and Orkney and Shetland Steam Navigation Co., Ltd., which is frequently seen in the port; the large suction dredger *Foremost Scot*, built in 1929 by Alex. Hall & Co., Ltd., for the James Dredging Towage and Transport Co., Ltd.; and the *Kini*, a 230 ft. timber-carrying vessel, built in 1930 by John Lewis & Sons, Ltd., for the Union Steamship Co. of New Zealand, Ltd.

Soap.—Aberdeen has always enjoyed a large soap-making trade. At the local works of Messrs. Ogston & Tennant, Ltd., one of the oldest established soap manufacturers in the country, all kinds of soaps are made—household soaps, soft soap, toilet soap, soap flakes, textile and laundry soaps, etc.

Woollens.—At the head of the woollen trade of Aberdeen stands pre-eminently the great firm of J. & J. Crombie, Ltd. By gradually adding to buildings as their business extended, their works at Grandholm now cover many acres, and their factory alone is twice the size of any other in the woollen trade in Scotland. The speciality of this important firm is the manufacture of high-class overcoatings, and their goods are world-renowned.

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XVIII.

SCIENTISTS OF THE NORTH-EAST OF SCOTLAND

A.—PHYSICS, CHEMISTRY, GEOLOGY, BOTANY, MEDICINE

BY

G. M. FRASER (City Librarian).

Introductory.—It will not be a surprise to anyone to find that in the multitude of eminent persons produced in this part of the country in the past five hundred years persons of intellect rather than persons of imagination have largely predominated. To some extent comparative poverty, which necessitates action, and severity of climate, which affects temperament, encouraged the development of the more useful qualities in the population, and of those who have reached the height of even moderate fame most have represented the arts of civilisation rather than the graces of literary excellence in either poetry or prose. Although Aberdeen gave to Scotland an early and great poet in John Barbour, our authority on the Bruce period, he flourished as an historical poet, who not only steadily keeps in touch with actual affairs, giving little evidence of emotional fancy, but derives his entire virtue from that characteristic quality in his work. And then the circumstance of geographical isolation in this corner of the land for centuries induced a habit of independent thought that gave direction, if not altitude, to mental effort in all regions of professional achievement. Even in the realm of philosophy, the one system of abstract thought which, in Thomas Reid, originated in the north-east of Scotland, is universally characterised as the Philosophy of Common Sense. As we shall see presently, the Aberdeen region produces men of science in profusion. Teachers, theologians, journalists, competent men of business, and travellers abound, but only in rare cases does the district throw off men of high creative power. In the speculations of all of them the practical categories are dominant. In the following list of eminent men of science who have been connected or associated with Aberdeen, only outstanding cases have been selected, and the number had to be limited.

Physics.

Arnott, Dr. Neil.—Born in 1788, Neil Arnott was a graduate, M.A., of Marischal College and University, Aberdeen, and obtained the diploma of the College of Surgeons, London, in 1811. He was a popular lecturer in London on chemistry and natural philosophy, and in 1827 he published the first volume of his *Physics*. ‘ It was received with a burst of unanimous commendation such as has never been given to any scientific work before or since.’ (Alexander Bain, 1875.) In 1859 Neil Arnott was

present at the meeting of the British Association in Aberdeen, the guest of Lord Provost Webster—afterwards M.P. for the city—at whose instance the Association visited Aberdeen. Neil Arnott became a wealthy man, and made endowments in all the four Scottish Universities.

FORBES, Prof. JAMES DAVID.—He was born in Edinburgh, 1809, his father being Sir William Forbes, Bart., of Pitsligo, Aberdeenshire, friend and trustee of Sir Walter Scott. His mother was Williamina Belches, known as Scott's first love. Forbes, who became Principal of the United College of St. Andrews in 1859, acquired eminence from his remarkable studies on climate, glaciation, etc. In 1831 he co-operated with his friend Sir David Brewster in the foundation of the British Association. He was offered the Presidency of the Association in 1864, but owing to the state of his health he was obliged to decline.

FORSYTH, Rev. ALEXANDER JOHN, LL.D.—Rev. Dr. Forsyth is now well remembered as the inventor of the percussion lock, and as having been the first to substitute fulminate for flint as a means of igniting the charge of gunpowder. He was the son of Rev. James Forsyth, Manse of Belhelvie near Aberdeen, and was born at the Manse of Belhelvie in December 1768. He succeeded his father in the charge of Belhelvie, 1791. His invention of the percussion lock has been acknowledged as of the highest national importance, and a remarkable commemoration of his work was the unveiling, five years ago, of a tablet to his memory in the Tower of London, where Dr. Forsyth carried out experiments on his invention in 1806, and the unveiling of a replica of the Tower of London tablet in King's College, Aberdeen, in 1931.

HAMILTON, Prof. ROBERT.—Hamilton, who was a son of Gavin Hamilton, a well-known bookseller and publisher in Edinburgh, was appointed to the chair of Natural Philosophy in Marischal College, Aberdeen, 1779, but in 1817 was appointed to the chair of Mathematics. His most distinctive public service was his exposure of the unsoundness of the management of the British National Debt, published in his *Inquiry*, 1813, second edition 1818, which led to a revolution in the national financial system.

THOMSON, Prof. DAVID.—David Thomson, born in Leghorn, 1817, the son of a Scottish merchant, was a graduate of Glasgow and Cambridge. He was Professor of Natural Philosophy in the reconstituted University of Aberdeen, 1860, and although his published work is limited to the article 'Acoustics' in the *Encyclopædia Britannica*, he was of great practical use in connection with the movement for university extension and reform.

WATT, JAMES.—The interest of Aberdeen in this illustrious mechanical genius rests on the probability that his grandfather, Thomas Watt, was for a time a farmer in Aberdeenshire, and that Watt's earlier forbears sprang from the Aberdeenshire soil. It is pointed out that Thomas Watt, farmer at Kintore, Aberdeenshire, is the Thomas Watt who appears as a teacher of mathematics and navigation in Greenock, whose younger son, James Watt, dealer in nautical instruments and stores, was the father of the inventor.

Chemistry.

Brown, Prof. J. Campbell.—The son of an auctioneer in Aberdeen, and, after graduation, assistant to the Professor of Chemistry in Marischal College, 1864, Brown went to Liverpool School of Medicine as lecturer on Experimental Science and Toxicology. He was one of the foremost spirits in promoting the scheme for a University College in Liverpool. When this was accomplished he was appointed to the chair of Chemistry in the new college. He was an authority on the latent heat of vaporisation of liquids.

Mackaile, Matthew.—This was a very early apothecary in Aberdeen. He was also a writer of books of some quality. His earliest known work is *The Diversitie of Salts and Spirits maintained*, published in Aberdeen, 1683. For the printing of this book, John Forbes, the Town's Printer, was reprimanded by the Town Council in respect that the work reflected on other physicians and chirurgeons in the burgh.

Geology.

Cruickshank, Alexander.—The accomplishments of this man, although he was deformed and paralysed from birth, were little short of marvellous. He was the son of Prof. Cruickshank, of the chair of Mathematics in Marischal College and University. Having graduated with ' honourable distinction ' at the University in 1840—bracketed equal with Alexander Bain, afterwards Professor, and Rector of the University—he devoted himself to study, geology and meteorology taking first place in his cultured interest. He was made LL.D. in 1882.

Longmuir, Rev. John.—This many-sided man, an accomplished geologist, did his most important work in lexicography. In revising Jamieson's *Scottish Dictionary* he produced a work that was more valuable than the original, and corrected Jamieson on the sources of the dialect speech of Scotland in a fundamental sense. He was an LL.D. of King's College, 1859, and was one of the Secretaries of the Geology Section of the British Association in connection with the visit of the Association to Aberdeen in 1859.

Miller, Hugh.—It does not appear that Hugh Miller ever actually visited Aberdeen, although on two occasions he passed it on his way to Leith by the ' smack,' but his celebrity attaches rather to the whole north of Scotland. He was in contact with Prof. Fleming, the geologist, of Aberdeen, and doubtless owed something to the association. The bust in the National Portrait Gallery, Edinburgh, is by William Brodie, an Aberdeen sculptor.

Mitchell, James, LL.D.—He was a graduate of King's College and University, Aberdeen, and in London wrote much on the sciences, including geology. His most remarkable production was the compilation *The Scotsman's Library*, 1825, a singular collection of out-of-the-way facts, all carefully indexed.

Nicol, Prof. James.—Nicol, a Peebles-shire man, was Assistant Secretary to the Geological Society, London, 1847 to 1849, when he went

to Cork as Professor of Geology. In 1853 he was appointed to the chair of Natural History in Aberdeen. His distinctive contribution to the literature of his subject was the share he contributed, through papers to the *Journal of the Geological Society*, in solving the problem of the parallel ' roads ' of Glen Roy.

BOTANY.

BEATTIE, Prof. JAMES.—He was a nephew of Prof. James Beattie, of *The Minstrel*, with whom he is generally confused. He became Professor of Civil and Natural History in Marischal College, 1788, his uncle being Professor of Moral Philosophy and Logic in the same college.

BROWN, ROBERT, D.C.L.—A native of Montrose, and a student of Marischal College, he devoted a large part of his life to exploring the vegetable world of New Holland and Van Dieman's Land. He was Librarian to the Linnean Society, also to Sir Joseph Banks, and latterly Keeper of the Botanical Collections of the British Museum.

DAVIDSON, Rev. GEORGE, LL.D.—Born 1825, he was a native of Crathie, opposite Balmoral Castle, and was minister of Logie Coldstone, between the Dee and the Don, for nearly half a century. His chief interest, apart from parochial duties, was microscopic botany, and in the course of his investigations in his own locality he discovered kiesselguhr deposits in the district of Cromar that were afterwards largely used in the manufacture of dynamite.

DICKIE, Prof. GEORGE.—Dickie has been familiar to generations of botanists in the north-east of Scotland through his *Botanist's Guide* to the district, 1860, his *Flora Aberdonensis*, 1838, and other publications bearing on the plant life of the north-east of Scotland. He was the first Professor of Botany in the reconstituted University of Aberdeen, 1860.

FORSYTH, WILLIAM.—Bred as a gardener at Oldmeldrum, Aberdeenshire, Forsyth went to London, 1763, and found employment in the Apothecaries' Garden at Chelsea. He became Head, and was afterwards Superintendent of the Royal Gardens of St. James's and Kensington. He had the remarkable distinction of receiving the thanks of both Houses of Parliament for his treatment of diseased trees.

KING, Sir GEORGE.—George King was raised in a literary atmosphere in respect that his family were engaged in the bookselling business in Aberdeen. He graduated M.B. at Marischal College, 1865, and presently went to India, where he did his life's work. On the discovery of his botanical attainments he was made Acting Superintendent of the Saharanpur Botanical Gardens, 1868; subsequently he was transferred to the Forestry Department of the North-West Provinces, and afterwards, 1871, he was made Director of the Botanical Survey of India. The Royal Botanical Gardens at Calcutta were planted by him, and during his period of office productions of the nurseries of economic and other useful plants that he established were distributed to all parts of the world. He received from his own university the honorary degree of LL.D. in 1883, and his knighthood in 1886.

Low, George.—He was born in 1747, near Brechin, and in the Orkneys he devoted most of his life to observation and investigation of the natural history of the Northern Isles. He was with Sir Joseph Banks when Banks visited the Orkneys in 1772, and was also in correspondence with Thomas Pennant, whose correspondence with Gilbert White at the time was to result in the *Natural History and Antiquities of Selborne.*

MacGillivray, Prof. William.—MacGillivray has taken his place as distinctively the greatest naturalist that the North of Scotland has produced. He graduated at King's College, M.A., in 1815, and made some effort afterwards to take up medicine, but abandoned it for natural science. He became, in 1831, the Servitor of the Museum of the Royal College of Surgeons, Edinburgh, but resigned this post in 1841, when to his great happiness he was appointed to the chair of Natural History in Marischal College and University. MacGillivray, as a Professor, embarked on many undertakings besides the delivery of his lectures—in making collections for the use of his students, in descriptive works on natural history and, greatest of all, his *History of British Birds.* His last completed work before his death in 1852 was *The Natural History of Deeside*, the manuscript of which was printed by command of Queen Victoria and was presented by the Prince Consort to individual recipients. In November 1900 a brass memorial tablet was unveiled in the Natural History Classroom, Marischal College, and was delivered to the custody of Prof. (afterwards Sir) J. Arthur Thomson, MacGillivray's successor in the chair of Natural History. Another form of commemoration was the provision of a granite monument of artistic design placed at MacGillivray's grave in New Calton Burying Ground, Edinburgh.

Morrison, Robert.—This early botanist was born in Aberdeen, 1620, and graduated M.A. and Ph.D., 1638. He took the degree of M.D. at Angers. While in France he was introduced to Charles II, and at the Restoration accompanied the King to England, and was made King's Physician, King's Botanist and Superintendent of the Royal Gardens.

Medicine.

Abercrombie, John.—Dr. Abercrombie was a son of the minister of the East Church in Aberdeen, born 1780. He took his medical course at Edinburgh University, and settled down there as a practising physician. He was first physician to the King, George III, in Scotland, a dignity always conferred on the most distinguished doctor of his time in Scotland. Among his distinguished patients was Sir Walter Scott, whom he advised to stop writing if he did not wish to kill himself. In 1835 he was elected Rector—usually styled Lord Rector—of Marischal College and University, and again in 1836 and 1837.

Arbuthnot, John.—It is amusing to think that the designation 'John Bull,' as typical of the Englishman, is due to the humour of an Aberdonian. Dr. John Arbuthnot, a graduate in Arts of Marischal College and University, 1681, and the first recorded M.D. of St. Andrews, 1696, published, in 1712, the first part of his celebrated satire, *The History of John Bull*, and from that day the symbolic expression, as applied to an Englishman,

was fixed. While in practice in London, and physician to Queen Anne, Arbuthnot was the familiar associate of Pope, Swift, the poet Gay, Matthew Prior, and other literary celebrities of his time.

Bannerman, Donald.—In the time of David II, King of Scotland, 1324–1371, Donald Bannerman, an Aberdonian, was physician to the King. Little is known about Dr. Bannerman except that he was of the well-known local family, still represented by the Bannermans of Elsick, and that he received grants of property from the King in the northern suburb of Aberdeen.

Barclay, William.—This scholarly physician was born about 1570, and although he travelled—and doubtless practised—extensively throughout Europe for about thirty years he never lost affection for Aberdeen. In a poetic tribute to the Well of Spa, Aberdeen, constructed by another eminent Aberdonian, George Jamesone, the first British portrait painter of repute, Barclay declares its waters to be equal to the Spa of Liége.

Black, Patrick.—Born at Aberdeen in 1813, Dr. Patrick Black, noted physician of St. Bartholomew's, was a son of Col. Patrick Black of the Bengal Cavalry. He graduated M.D. at Oxford in 1836, and was elected Assistant Physician to St. Bartholomew's in 1842, Warden of its College in 1851, Physician to the Hospital, and, later, Lecturer on Medicine to the school.

Clark, Sir Andrew, Bart.—He was born, the son of a country doctor, at St. Fergus, Aberdeenshire, 1826. His mother died at his birth, and his father when the boy was seven years old. Educated at the Academy, Dundee, he became apprentice to a Dundee practitioner, but afterwards studied as an extra-academical student at Edinburgh, and took the diploma of member of the Royal College of Surgeons, England. By his good fortune in becoming acquainted with Mrs. Gladstone, in connection with the London Hospital, where he was physician, Clark became the medical attendant and personal friend of Mr. Gladstone, and many other patients of celebrity. In 1883 he was created a baronet, and F.R.S. in 1885. He was elected President of the Royal College of Physicians in 1888, and held that office till his death, 1893.

Clark, Sir James, Bart.—Born at Cullen, 1788, Banffshire, and a graduate, M.A., of Aberdeen University, Clark became in London probably the most fashionable physician of his time. The King of the Belgians—whom Clark had met on the Continent—was a patient of his, also the Duchess of Kent, mother of Princess Victoria, and when Victoria became Queen, Clark became the greatly trusted royal physician. He was made a baronet in 1838. His son, the late Sir John F. Clark, Bart., of Tillypronie, on Deeside, was also a personal friend of Queen Victoria. It was through the advice of Sir James Clark that the Queen and the Prince Consort purchased the property of Balmoral, on Deeside, as a summer residence for the royal family.

Cumyne, James.—This was the first known medical officer of Aberdeen. He was brought to the burgh about 1503, as the magistrates, on October 20 in that year, agreed to pay him a retaining fee of ten marks yearly, and,

later on, one-half of the net fishings at the fords of Dee, on condition that he should ' mak personale residence within the said burghe, and cum and vesy tham that beis seik, and schow tham his medicin.' As Cumyne is designated ' Master ' he was evidently a University graduate. He was made Professor of Medicine, the first, at King's College—known at first as the College of St. Mary. He is believed to have assisted Hector Boece, first Principal of the College, in the composition of his *History of Scotland*. Cumyne died about 1522.

Dun, Patrick.—Dr. Patrick Dun practised as a physician in Aberdeen with great success, and was Principal of Marischal College from 1621 to 1649. He was a wealthy man, and open-handed. One of his benefactions was 2000 merks to Marischal College for repair of damage caused by a fire in 1639.

Farquhar, Sir Walter.—This eminent London surgeon, whose story is told by Dr. James Mitchell, in his singular collection *The Scotsman's Library*, came from Peterhead. He became a student at King's College and University, and was befriended particularly by Prof. John Gregory. He settled in London as an apothecary, and made a fortune. He became physician to the celebrated Duchess of Gordon, and through this connection Farquhar became associated, as a physician and otherwise, with persons of the highest rank in England and Scotland. He died in 1820. Sir Walter was a generous man. Among other benefactions to the Aberdeen Medico-Chirurgical Society he presented to it, in 1815, the portrait of Harvey, which he had received from Lord Besborough, the most valuable portrait in the Society's possession.

Fordyce, George.—He was born in 1736, son of a small proprietor at Aberdeen, and graduated M.A. at Marischal College and University at the age of fourteen. In London, for thirty years, he taught Chemistry, Materia Medica, and Practice of Physic, carrying on at the same time the practice of a physician. He was admitted a Licentiate of the College of Physicians, was chosen physician to St. Thomas's Hospital, F.R.S. in 1776, Fellow of the College of Physicians, 1787, and between 1771 and 1802 he published about a dozen treatises on medical and chemical subjects. More remarkable than all, perhaps, was his being elected a member of the Club organised by Dr. Johnson, whose playful antipathy to Scotsmen was noted, and who may have had Fordyce, if not Boswell also, in view when he framed the fifth rule of the Club that ' every member present at the Club shall spend at least sixpence.' Fordyce died in 1802, an esteemed and eminent man.

Fordyce, Sir William.—The portrait, by Angelica Kaufmann, of Sir William Fordyce, founder of the Fordyce Chair in Agriculture in Aberdeen University, used to be considered the most valuable of the old pictures in Marischal College. He was a graduate of Marischal College, who, after serving in the continental wars of the eighteenth century, settled in London and developed a large and lucrative practice. He was F.R.S., was knighted, and was three times honoured by his old University in being elected Rector, in 1790, 1791, and 1792.

FRASER, Sir ALEXANDER.—The physician to Charles the Second, Fraser was of the ancient family of Frasers of Durris. He was markedly royalist in his views, a member of the Church of England, and when he accompanied Charles to Scotland in 1650 he proved particularly obnoxious to the Covenanters of his native country. He and others of his fellowship were described in September of that year as 'profaine, scandalous, and malignant,' but he may have been a very estimable gentleman for all that.

GREGORY, JOHN.—The Gregories are dealt with appropriately under Mathematics, but mention ought to be made here of Dr. John Gregory, one of the most distinguished members of an illustrious family. He was born at Aberdeen in 1724, the youngest of three children of James Gregory, Professor of Medicine at King's College and University, and grandson of the great mathematician. He himself occupied the chair of Medicine from 1755–6 to 1766 when he succeeded Rutherford in Edinburgh, being also appointed First Physician to the King in Scotland. From 1745 to 1747 he was a student at Leyden, where a fellow-student was 'Jupiter' Carlyle of Inveresk, in whose entertaining autobiography, edited by John Hill Burton, many interesting things are told of John Gregory.

HARVEY, WILLIAM.—But for the constraint of alphabetical order the name of this benefactor of the human race would have appeared at the top of all these lists of men of science. Before 1931 it would not have been possible to have included in a list of persons connected with Aberdeen, without doubt, the name of William Harvey. In that year, however, Dr. W. Clark Souter of this city, by most assiduous research in Aberdeen and elsewhere, established beyond uncertainty that William Harvey visited Aberdeen in August 1641—while on a visit with the King, Charles I, to Edinburgh—and that on August 20 he received the honour of being made a free burgess of the city, the most distinguished name in the burgess roll. Dr. Clark Souter's monograph, *Dr. William Harvey and Aberdeen*, reprinted from the *Aberdeen University Review* of November 1931, is one of the small books that, if it has not made history, in this respect has established it.

JOHNSTON, ARTHUR.—Dr. Arthur Johnston, born 1587 at Caskieben, Aberdeenshire (now Keith Hall, seat of the Earl of Kintore), is said to be the only physician who ever served poetry with his prescriptions. But he was a notable poet, in Latin particularly, whose competency in this respect was said to be superior even to that of George Buchanan. Arthur Johnston became a student of King's College—Rector in 1637—but his medical course was taken abroad, and he had the degree of M.D. from the University of Padua, 1610. He travelled subsequently in Germany, Denmark, Holland, and France, where he settled, and devoted himself largely to the cultivation of his remarkable aptitude for Latin verse.

McGRIGOR, Sir JAMES.—This distinguished army surgeon, whose impressive statue in bronze may be seen in the grounds of the Royal Army Medical College, London, was really the founder of the British Army Medical Service as known since the period of Wellington. James McGrigor, born in Strathspey, 1771, was a medical graduate of Marischal

College, and while still undergoing his medical course he founded the Aberdeen Medico-Chirurgical Society, 1789, and was himself its first secretary. In his after life he became distinguished as Director-General of the Army Medical Service. His public honours in London and Edinburgh were bewildering. In Aberdeen McGrigor is commemorated by a portrait in the Medical Society's Rooms, King Street, by Andrew Geddes, A.R.A., a friend of Wilkie, and the leading etcher of his time; by a portrait in Marischal College by William Dyce, R.A., a fellow-townsman of McGrigor and a graduate of the same College and University; and by the great granite obelisk in the Duthie Park, provided by relatives, which stood in the quadrangle of Marischal College from 1860 till the summer of 1906, when it was removed to the Duthie Park to make way for the new front portion of the Marischal College building, inaugurated by the King in the autumn of that year.

Moreson, Thomas.—Dr. Thomas Moreson seems to have practised abroad, and a volume of his on the transmutation of metals was printed at Frankfort in 1593, while another of his publications—very rare—on the Popedom was published in Edinburgh in 1594. He was a correspondent of Bacon and other notable public persons of the period.

Morison, Thomas.—A native and graduate of Aberdeen, Dr. Thomas Morison was the discoverer of Strathpeffer Spa. His father, Morison of Elsick, in Kincardineshire, was Provost of Aberdeen, 1744-45, when the burgh was taken possession of by the rebellious Jacobites. His brother was Rev. George Morison, D.D., minister of Banchory Devenick, near Aberdeen, who put up the notable suspension bridge over the Dee near his church, still in constant use. Dr. Thomas Morison inherited Elsick, also the property of Disblair, near Aberdeen. In the pump room at Strathpeffer may still be seen the fine portrait of Dr. Thomas Morison, provided by public subscription, 1724, by the place that he originated and made permanently notable.

Skene, Gilbert.—Dr. Gilbert Skene was the first of a long line of Skenes, medical practitioners in Aberdeen. He was appointed to the chair of Medicine in King's College in 1556, almost immediately after the Reformation. In 1568 Dr. Skene published 'Ane breve descriptioun of the Pest, quairin the causis, signis, and sum speciall preservatioun and cure thairof ar contenit, set furth be Maister Gilbert Skene, Doctour in Medicine. Imprintit at Edinburgh be Robert Lekpreok.'

B.—MATHEMATICIANS AND ASTRONOMERS

BY

GEORGE PHILIP, M.A., D.Sc.

The north-east of Scotland shared with the rest of the country in the intellectual revival that accompanied the Reformation, but it may cause some surprise to learn that there was no department of learning in which

greater advances were made than in mathematics. Until the end of the sixteenth century Scotland contributed nothing to the progress of the science, and the history of mathematics is entirely wanting in the name of even one man born north of the Borders before the middle of that century. Indeed, Britain as a whole lagged far behind other European countries, like France, Germany, and Italy, in her attachment to mathematical learning. It is therefore all the more surprising to find that in the period immediately succeeding the Reformation Scotland produced several mathematicians who won a European reputation. The name of John Napier of Merchiston, the discoverer of logarithms, comes readily to one's mind in this connection. The rudiments of the subject, a little arithmetic, Euclid's Elements, conic sections and astronomy on the Ptolemaic system were taught in the universities in a mild fashion, but those who wished to take up the study of the subject with some earnestness found it necessary to attend centres of learning on the Continent, mainly in France, Germany, and Holland.

LIDDEL, DUNCAN.—One of the earliest of such scholars was Duncan Liddel, a native of Aberdeen, who was born in 1561. At the age of eighteen he went abroad to Danzig, but on learning that Dr. John Craig taught mathematics at Frankfurt-on-the-Oder he went there, and a close friendship was thereafter formed between the two Scotsmen, which had a determining influence on Liddel's career. Craig, it may be remembered, figures in the controversy over the priority of discovery of logarithms. He was personally acquainted with Tycho Brahe and Kepler, and also with John Napier, and it is generally accepted that it was through Craig that Kepler first learned of Napier's achievement. Liddel took up the study of mathematics and astronomy at Breslau under Wittichius, one of the ablest of Tycho's pupils; and later he went to Rostock as a teacher of mathematics. It is claimed for Liddel that he was the first man in Germany to teach Copernican astronomy. He visited Tycho at Hveen in June 1587, but, as was the case with Kepler and others, the Danish astronomer conceived the idea that Liddel was taking credit to himself for some of his discoveries, a charge indignantly denied by Liddel. About 1590, attracted by the reputation of the newly established University of Helmstadt in Brunswick, Liddel took up his residence in that town, where he was appointed to the Chair of Mathematics. At this period it was by no means unusual for men to combine the teaching of mathematics with the practice of medicine. Liddel took the degree of Doctor of Medicine in Helmstadt in 1596, and for several years he carried on both professions. But in the course of a few years he acquired a large and lucrative practice among the principal families in Brunswick, and by his teaching and his writings he became the chief support of the Medical School at Helmstadt. In 1603 he resigned the Chair of Mathematics, and confined himself entirely to the teaching and practice of medicine. At this time the German universities, like our own, were passing through a very troubled period, and Liddel, advised it is thought by Dr. John Craig, determined to return to Scotland. He settled in Aberdeen and died there in 1613.

Part of his considerable wealth was bequeathed by Liddel for the foundation of a Chair of Mathematics at Marischal College, and part was left to the magistrates of Aberdeen for the education of poor scholars belonging to the city. His grave in the old Church of St. Nicholas is marked by a large tablet of brass, erected to his memory by the magistrates. As far as is known Liddel left no mathematical writings, but several MSS. on medical subjects written by him are now in possession of the University of Aberdeen. A *Life of Liddel* was written by Prof. Stuart of Aberdeen.

Anderson, Alexander.—From the mathematician's point of view, Alexander Anderson was a more distinguished Aberdeen product than Dr. Liddel. By an unpardonable oversight or neglect he was never sufficiently well known in his native country, and he is now all but forgotten. But Anderson was undoubtedly a big man in his day and was highly esteemed by his contemporaries on the Continent. Details of his life are scanty. In his writings he describes himself sometimes as 'Scotus' and sometimes as 'Aberdonensis,' and from this, as also from our knowledge of his blood-relations, we may safely assume that he was a native of the Aberdeen district. But his birthplace cannot be definitely located. He was a first cousin of David Anderson of Finshaugh—from the versatility of his talents nicknamed 'Davie Do A'thing'—whose daughter was the mother of James Gregory, the first of a distinguished line of mathematicians, of whom we shall have to speak later on. The date of Alexander Anderson's birth is fixed by the inscription on a print in the Bibliothèque Nationale, which is as follows: 'Alexander Andersonus Scotus Anno Aetat XXXV Salut MDCXVII.' From this it appears that he was born in 1582. As nothing is known of him after 1619 we may assume that he died about that time.

We are quite in the dark as to Anderson's early training in mathematics. There is no record of his attendance as a student either in Aberdeen or Paris, and the probability is that, like other young Scotsmen of that time, he pursued his studies in Holland or in Germany. At any rate the earliest definite information we possess regarding him is derived from the title-page of his first booklet, *Supplementum Apollonii Redivivi*, which was published in Paris in 1612. In the brief biographical notices that have appeared regarding him it is stated that he was a professor of mathematics in Paris, but it must not be understood that he ever held an official position in Paris. It can only mean that he taught mathematics privately, although in the prefaces to his many writings Anderson never alludes to teaching either in the university or in a private capacity. But he does refer on one or two occasions to the scanty returns he received for his labours. One blessing for which he is thankful, however, he does record, and that is that fate permitted him to live in a kindly climate and not 'on the shores of Britain where the bitter north wind blows.'

In the prefaces to his writings we occasionally get glimpses of his character, and from these we can gather that he was of a generous and peaceful disposition, possessing none of the jealous feeling which seems to have actuated some of his contemporaries towards their mathematical rivals. In the appendix to the *De Aequationum Emendatione* he writes

with reference to those who accuse him of plagiarising from Vieta 'that it is not the part of a peaceful mind to seek praise for itself by injuring the name of others . . . and if any praise comes to me from this, and if you think that it has been taken from you, you should attempt to restore the loss, if you can do anything worthy of the light.' He is here addressing those who 'earnestly pursue the study of Mathematics.'

Anderson's claim for recognition as a mathematician rests largely but not entirely on the work he did in preparing Vieta's writings for publication. This was no light task, as Vieta, not a professional mathematician but a state official, had little time for preparing his writings for publication, with the result that his note-books, in which he jotted down his conclusions, either with very incomplete proofs or none at all, were apt to be unintelligible even to a trained mathematician. After his death in 1603 his MSS. remained untouched for several years and were in danger of being lost, until Anderson was invited to prepare them for publication. It was not, however, until 1646 that the Elzevir Press published Vieta's collected writings under the supervision of Van Schooten, the Dutch mathematician. But the publishers put on record that they had the privilege of using the MSS. prepared by Anderson. The selection of Anderson as editor of Vieta's writings is ample testimony to the high place he held among his contemporaries as a competent mathematician, and when we reflect upon the importance of the discoveries of the great French mathematician, we are not asking too much in claiming for Anderson a share of the distinction that by right falls to the 'father of modern Algebra.'

The most elaborate of Anderson's writings *De Aequationum Recognitione et Emendatione* deals with Vieta's treatment of equations. Owing to the use of many terms, now long obsolete, it is very difficult to read. Like all scientific treatises of the time it is, of course, written in Latin. In the appendix he shows that the problem of trisecting an angle may be made to depend on the solution of a certain cubic, and he gives a very neat geometrical proof that the cubic must have three roots. Throughout his writings Anderson gave many examples of the use of algebraic geometry, and, indeed, in some respects, he anticipated Descartes who lived shortly after him. He had much in common with Ghetaldo, a contemporary writer whose influence in establishing the principles of analytical geometry is now being recognised. Anderson was in advance of his time when he wrote 'that all the circumstances of a problem in analysis should be deducible from the consideration of equations.' It has to be kept in mind that symbolic algebra was only coming into use in Anderson's day.

But Anderson was well versed in all the questions that agitated the mathematical world during the end of the sixteenth and the early years of the seventeenth century. He wrote on Maxima and Minima, on the Quadrature of the Circle, on Determinate Section where his attempts to restore the lost books of Apollonius called for commendation from Robert Simson, and on Diophantine Analysis. One of his most extensive writings is *On Angular Sections*, which deals with the trigonometry of multiple and sub-multiple angles. Many of the propositions were previously given

by Vieta, but Anderson supplied the proofs and gave additional theorems. One of the propositions deals with the problem propounded by Van Roomen, a Dutch mathematician, to Vieta, in which it is required to solve a certain equation of the forty-fifth degree. Vieta solved it in a few minutes, having recognised from the coefficients occurring in it that it merely involved the division of an angle into forty-five equal parts.

Anderson wrote seven pamphlets or tracts, all between the years 1612 and 1619. He was apparently his own publisher, and in one of his prefaces he tells that many copies of his books were still on his hands. Probably they never got into circulation, a fact which may account for the extreme scarcity of his writings now. It is doubtful if there are half a dozen complete sets of his writings in Great Britain to-day, and no complete account of them has as yet appeared in our language.

The Gregory Family.—This family occupied an unusually distinguished place in the history of science in Scotland. In the course of three generations no fewer than sixteen members of the family occupied chairs in British universities, their allegiance being divided between mathematics and medicine. For almost a century they practically monopolised the teaching of these subjects in Scotland. The only parallel that exists in the history of mathematics is that of the Bernouillis in Switzerland and Germany. The first and probably the ablest of the Gregories, James Gregory, was the son of the Rev. John Gregory, minister of the parish of Drumoak in Aberdeenshire, and he was born at Aberdeen in 1638. His mathematical ability may have been inherited from his mother's people, she, as has already been stated, being one of the Anderson family, of which Alexander Anderson was a member.

James Gregory studied at Marischal College, and soon gave evidence of great inventive and mathematical skill. At the early age of twenty-four, he published his *Optica Promota*, in which he showed that a reflecting telescope could be constructed, which would be a considerable improvement over the hitherto employed Galilean type. At that time the University of Padua was at the height of its fame, and, attracted by the brilliance of its teaching, Gregory spent several years there, and published the first of his geometrical writings, *Vera Circuli et Hyperbolae Quadratura*, during his residence at the Italian University. In this tract he showed from geometrical considerations that the area between the asymptotes of a hyperbola and the curve could be expressed as a convergent series and also as a logarithm, thus establishing the first logarithmic expansion. It will come as a surprise to many persons, even to mathematicians, to hear that the logarithmic series was known for some years before Newton made known the binomial expansion. At this time Gregory produced original papers on the quadrature of curves, and on the inverse method of tangents or the integral calculus, as we would now call it, which attracted the attention of Newton, Huygens, Wallis, and other leading mathematicians of the period. In 1668 he followed up his previous activities by publishing his *Exercitationes Geometricae*, which firmly established his reputation as one of the foremost mathematicians in the country. On the Chair of Mathematics at St Andrews becoming vacant in this year, Gregory was

elected to it, and he remained there for six years until his appointment to a similar chair in Edinburgh University. But his tenure only lasted for one year. In October 1675, while showing the satellites of Jupiter through a telescope to some of his pupils, he was suddenly struck with blindness and died a few days afterwards at the early age of thirty-seven. Nowadays his name is chiefly remembered in connection with the series for expressing the inverse tangent of an angle in terms of the angle, a series which readily gives a value for π. But his whole work on series and on quadrature of curves largely paved the way for Newton's method of fluxions and, if for no other reason, he is justly entitled to a place among the hierarchy of mathematicians.

In 1669 Gregory married Mary, the daughter of George Jamieson, the celebrated painter, the Vandyck of Scotland. His son, also James by name, held the Chair of Medicine in Aberdeen, and his son again was the famous Dr. John Gregory who helped to establish the fame of Edinburgh School of Medicine. But scientific ability was not confined to the family of the first James Gregory. His brother, David Gregory of Kinnairdy in Aberdeenshire, a successful merchant who commenced his commercial life in Holland, had the unique distinction of seeing three of his sons occupying Chairs of Mathematics in three British Universities. His eldest son David was born in Aberdeen in 1661 and was educated at Aberdeen and Edinburgh. It is said that he was led to the serious study of mathematics by carefully perusing his uncle's papers which came into his hands. When only twenty-three years of age, he was appointed Professor of Mathematics at Edinburgh University, and he soon attracted the attention of scientists throughout the country by the ability and zeal which he showed in teaching the newly published Newtonian principles. When Dr. Bernard, the Savilian Professor of Astronomy at Oxford resigned, Gregory was appointed to succeed him, his candidature being strongly supported by Sir Isaac Newton and Flamsteed, the Astronomer Royal. In 1702 his *Astronomiae Physicae et Geometricae Elementa* was published. This is reckoned as his greatest work, and was esteemed by Newton as an excellent explanation and defence of his philosophy. In the prosecution of a scheme which was initiated by Bernard for preparing editions of the works of the great Greek mathematicians, Gregory undertook to do Euclid's works, and in 1703 his *Euclidis quae supersunt omnia* appeared. Until the issue of Heiberg and Menge's edition (1883–88) this was still the only complete edition of Euclid. Along with Halley, who was at that time his colleague as Professor of Geometry at Oxford, Gregory had begun to prepare an edition of Apollonius, but he had not gone far in this undertaking when he died in 1710, and Halley was left to complete the work. Of David Gregory's other writings the most interesting is a small book on *Practical Geometry*, which was afterwards translated into English by Maclaurin and published in 1745.

James, the second son of David Gregory of Kinnairdy, succeeded David in the Mathematical Chair in Edinburgh University, and Charles, the third son, was appointed Professor of Mathematics in St. Andrews in 1707. He held the chair until 1739, when he was succeeded by his son, David Gregory, who lived until 1763.

MACLAURIN, COLIN.—The purely Celtic part of Scotland has not been so productive of mathematicians as the sister island, Ireland, has been, but one outstanding man at least has come from the Gaelic-speaking west, namely, Colin Maclaurin. He was born in 1698 in Glendaruel, the Argyllshire parish in which his father was minister. At an age when boys nowadays are only in the primary school, Maclaurin enrolled as a student in Glasgow University, where in due course he took his degree of Master of Arts. His great precocity attracted the attention of Robert Simson, the Professor of Mathematics, whose name should be well known in Scotland as the editor of the *Euclid* on which so many generations of Scotsmen were reared. It was Maclaurin's intention to study for the Church, and with that in view he read privately at home for a year or two. But during this period his taste for mathematics still further developed, and on a vacancy occurring in the Chair of Mathematics in Marischal College in 1717, he was induced to become an applicant. In those days vacancies in professorships in Aberdeen were filled by competition, and in this instance the examination lasted over a period of ten days. In spite of his extreme youth—he was only nineteen years of age—Maclaurin was successful, one of the competitors being Alex. Malcolm, a well-known teacher in Aberdeen. During his tenure of the chair, the study of mathematics in Marischal College was greatly stimulated, and, as was subsequently the case when Maclaurin went to Edinburgh, it almost became fashionable to be reckoned as a member of the mathematical class at the University. Visits to London in 1719 and 1721 brought him into contact with Newton, and he was elected a member of the Royal Society. From that time onwards a steady stream of papers from his pen appeared in the *Transactions* of the Society which readily established his reputation as a mathematician, and gained for him the friendship and esteem of Newton, Clarke and other leaders of the scientific world of the day. Maclaurin's earliest writings dealt with the geometry of higher plane curves, a subject which he attacked from a point of view that would now be described as projective. In 1725 he became Professor of Mathematics in Edinburgh University, and held the appointment till his death in 1746. His greatest work is his *Fluxions*, a two-volume lecture.

MALCOLM, ALEXANDER.—Alexander Malcolm deserves mention as author of a treatise on Arithmetic, published in London in 1730, and described by De Morgan as ' one of the most extensive and erudite books of the eighteenth century.' He was held in great esteem in Aberdeen as a teacher of mathematics, and besides the above compendious work was author of *A Treatise on Arithmetic and Book-keeping in the Italian Method*, published in 1718, and *Treatise on Music* in 1721.

TRAIL, WILLIAM.—William Trail, a student both of Marischal College and Glasgow University, held the Chair of Mathematics in the former from 1766 to 1779, when he resigned on his appointment as Chancellor of the Bishopric of Down and Connor in Ireland. He was the author of *Elements of Algebra for the Use of Schools and Universities*, published anonymously in 1778, and of a *Life of Robert Simson*, under whom he studied mathematics in Glasgow.

Ferguson, James.—A century ago probably no scientific man was better known, by name at least, among all classes in Great Britain, than James Ferguson, and no books were to be found more frequently than his on the bookshelves, both of professional scientists and of artisans. He wrote and lectured on astronomy, mechanics, optics, and electricity, and the rapidity with which new editions of his books had to be prepared can bear comparison with the career of many of the 'best sellers' of the present day. His *Astronomy explained upon Sir Isaac Newton's Principles*, first published in 1756, went through five editions in sixteen years; his *Lectures on Select Subjects in Mechanics* through four editions in twelve years; and *An Easy Introduction to Astronomy for Young Gentlemen and Ladies* through three editions in four years. The first of these books went through no fewer than thirteen editions, the last appearing in 1821.

James Ferguson was born in 1710 in the parish of Rothiemay in Banffshire, his parents being of the cottar class. Owing to the poverty of his home he received only three months' actual teaching, and that was received in Keith Grammar School. At an early age he was employed as a shepherd and before he was out of his teens he had made a reputation for skill in mending clocks and watches, and also in making portraits of local celebrities. During his leisure hours as a shepherd he began to study the movements of the heavenly bodies, and among his earliest mechanical inventions were instruments for representing the positions and movements of the moon and the stars. His talent for portrait painting attracted the attention of several persons of importance in the north-east of Scotland, and at their instigation he was persuaded to take up his residence in Edinburgh where he might get instruction from competent masters. But lack of means prevented Ferguson from taking full advantage of the opportunities thus offered to him, and after a period of residence in Edinburgh and Inverness, he determined to remove to London, where he hoped to find a wider outlet for his portrait painting and his mechanical inventions. For several years he carried on both activities, but his ambition was to be able to earn his living by lecturing on natural philosophy. In 1761 the King granted him an annuity of £50, and in 1763 he was elected a Fellow of the Royal Society. He gave courses of lectures, not only in London but in Cambridge, Bristol, Bath, and Liverpool, and so popular did they become that he was invited to pay several return visits to these cities. As a result his financial circumstances were greatly improved. The success of his lectures was largely due to his ingenuity in devising mechanical illustrations of the principles he wished to teach, his astronomical clocks, orreries, planetaria, etc., becoming famous throughout the whole country.

Ferguson, although a popular lecturer, was in no sense a 'quack.' Among the leading scientific men of the day he was highly esteemed, by none more so than Sir David Brewster, who edited the later editions of several of his books. The great diffusion of scientific knowledge among the mechanics of this country, which led to the establishing of institutes and technical colleges about the middle of last century, was largely due to the influence of Ferguson's writings. He died in London

in 1776. His youngest son John studied medicine in Aberdeen from 1773 to 1777, but, as far as is known, neither he nor any other member of Ferguson's family achieved distinction in any walk of life.

Clerk Maxwell, James.—Maxwell's association with Aberdeen dates from 1856, when as a young Cambridge graduate he was appointed to the Chair of Natural Philosophy in Marischal College, a position he held until the fusion of the two colleges in 1860.

Lamont, John.—As the wonderful career of Johann von Lamont is being made the subject of a separate paper nothing more of a biographical nature need be said here than that, born in Braemar in 1805, and starting life as a schoolboy in the tiny hamlet of Inverey, this remarkable man eventually became a Professor of Astronomy in Munich Observatory in 1852, and died in 1879, full of academic honours and one of the foremost astronomers in Europe.

In the domain of pure astronomy Lamont's name is chiefly associated with observations on the satellites of Uranus, the main object of which was to find their elongation so as to determine the mass of the planet. In the course of his investigations in 1837 he observed the most distant of the six satellites, the only verification hitherto obtained of Sir William Herschel's observations regarding the existence of satellites other than those discovered by him in 1787. But Lamont's most extensive work was in the department of terrestrial magnetism, where he was one of the pioneers and one of the most enthusiastic investigators. The connection between sun-spot periods and magnetic disturbances is one of his discoveries. In 1840 it was determined to form an international scheme for magnetic observations, and Lamont's previous experience and organising ability proved invaluable in putting the project into working order. He himself devoted great attention to the surveys of Northern Germany and South-West Europe, the results of which are embodied in two extensive memoirs. In addition to these, he was the author of very many papers on terrestrial magnetism and astronomy contributed to scientific societies in Britain and in Germany.

Gill, Sir David.—This celebrated astronomer was born in Aberdeen on June 12, 1843. His father was the head of a firm of watchmakers which had their headquarters in Aberdeen for several generations. David Gill received his school education at Dollar Academy, later proceeding to Aberdeen University. He read mathematics with David Rennet, the renowned Aberdeen teacher, the 'extramural professor' who has several wranglers to his credit. In natural philosophy Gill attended the lectures of Prof. David Thomson at King's College and of Prof. Clerk Maxwell at Marischal. The latter a few years afterwards referred to Gill as one of the ablest students he had through his hands in Aberdeen. After a year spent at Besançon in learning the art of clock-making, he returned to Aberdeen to take an active part in the conduct of the family business, his sense of duty to his father and the family causing him to sacrifice his natural inclination towards science and astronomy. But he did not regret the time so spent. The workshop practice he gained in his youth gave him skill in devising astronomical

instruments that was of inestimable advantage to him in later life. An invitation, however, from Lord Lindsay to Gill to become the superintendent of the newly established private observatory at Dunecht in Aberdeenshire proved too strong, and after a few years in business he severed his connection with his father's firm. An expedition to Mauritius in 1874-75 to observe the transit of Venus brought Gill's organising ability and observing skill to the notice of the astronomical world, and it became clear that his services could not be retained for long at Dunecht. In 1877 he led an expedition to Ascension to observe the opposition of Mars, the object of which was to obtain the necessary information for making an accurate determination of the sun's distance. Gill's work with his heliometer in this expedition excited the admiration of astronomers all over the world. In 1879 he was appointed His Majesty's Astronomer at the Cape of Good Hope, and it was there he built up his international reputation as an astronomer of distinction. During his period as Director he transformed the badly equipped observatory into a magnificent institution with the finest observing instruments in the world. In 1907, the year of his Presidency of the British Association, he retired and devoted himself to astronomical work and to the task of completing his book, *The History and Description of the Cape Observatory*. He died on January 24, 1914, and was buried in Old Machar Churchyard, Aberdeen.

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